

AIR FORCE JOURNAL *of* LOGISTICS

Logistics

Oil and Fuel

War Without Oil: Catalyst for Transformation
Fuel Hedging: Lessons from the Airlines

also in this edition:

Risk Analysis: F-16 Block 60 FLIR-
Assisted Landing Instruction
Baffled by DAFL: Directive Authority
History for Logistics
Inside Logistics
Candid Voices

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Special Feature

Although the Department of Defense uses approximately 1.8 percent of the 20 million barrels of oil consumed each day in the US, it is the largest single institutional energy customer in the United States and likely the world.

logistics oil and Fuel

War Without Oil: Catalyst for Transformation Fuel Hedging: Lessons from the Airlines

“War Without Oil: Catalyst for Transformation” objectively explores the strategic energy leadership role the Department of Defense (DoD) can play within the context of its national defense mission and President Bush’s 2006 Advanced Energy Initiative. By examining current and projected global energy and security environments, the energy roles of various branches of the federal government, and the unique responsibilities and characteristics of the DoD as America’s largest single energy consumer and security instrument of national power, the author analyzes whether a methodology exists in which the DoD can lead an immediate, coherent, and viable long-term strategy toward a vision of replacing petroleum as its primary energy source while maintaining all necessary strategic and operational capability to guarantee US security to 2050 and beyond. By envisioning and actively creating a post-petroleum military, the DoD not only

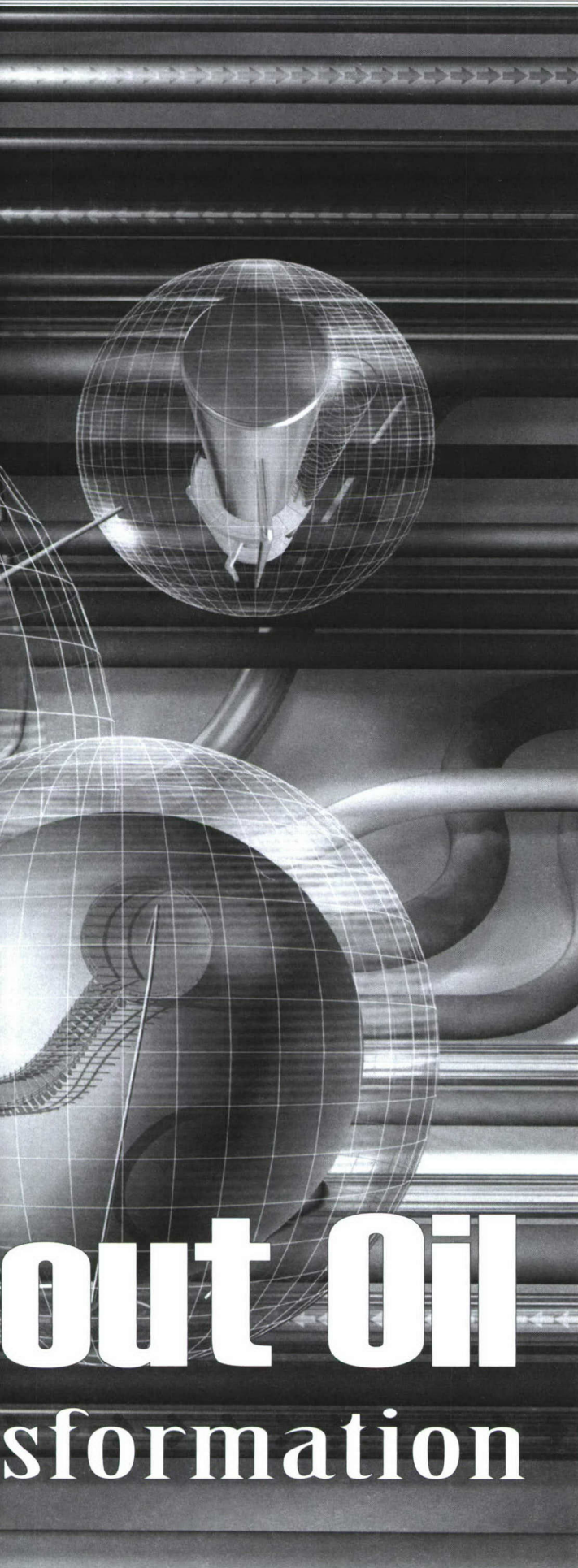
guarantees the *American way of war* and national security in an increasingly energy-insecure and complex security environment, but also obligates the organization to undertake such an endeavor as a transformational lever, catalyzing the best of government, industry, and the private sector as a positive force for a more secure world.

In “Fuel Hedging: Lessons from the Airlines” the author argues that developing a risk management strategy would allow DoD to hedge against unwanted budget risks. Hedging eliminates (or at least reduces) oil price volatility, smooths the budget, and improves cash management. Hedging also reduces price distortion that results from charging internal customers a *stabilized price* that does not reflect market prices and thus, does not reflect the actual cost of government purchased energy commodities.



Lieutenant Colonel Michael J. Hornitschek, USAF

War With Catalyst for Tran



out Oil sformation

Introduction

Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world. The best way to break this addiction is through technology.

—President George W. Bush,
State of the Union Address,
31 Jan 2006¹

On 31 January 2006, President Bush pronounced in his annual State of the Union Address, that “America is addicted to oil,” and that the key to eliminating US dependence on foreign energy was through the application of breakthrough technologies as part of his Advanced Energy Initiative (AEI).² Focused on revolutionizing energy sources and uses for facilities and automotive applications, the President proposed increasing Department of Energy (DoE) research and development (R&D) funding by 22 percent to accelerate technologies in clean coal

**Special
Feature**

consumption, nuclear energy, solar, wind, biofuel renewables, hybrids, and fuel-cells in order to move beyond a petroleum-based economy.³ The President’s AEI represents one of the numerous energy independence proposals to surface on the nation’s agenda since the Arab oil embargo of 1973. Despite decades of effort by government institutions, industry, and academia to free America of its petroleum *addiction*, the simple fact is that over the last 30 years American oil consumption has increased by one-third and imports have more than doubled. By 2025 the Energy Information Agency predicts that Americans will be importing 68 percent of their petroleum needs.⁴

Although the DoD uses only approximately 1.8 percent of the 20 million barrels of oil consumed each day in the US, it is the largest single institutional energy customer in the United States and likely the world.⁵ Subscribing to a National Defense Strategy that values effectiveness over efficiency, the DoD relies upon petroleum to deliver the energy-intense global power projection, agile logistics, and operational maneuver capabilities essential to waging a dominant and uniquely high-technology *American way of war*. As the nation’s primary security provider, the DoD has a vested interest in ensuring that it possesses the uninterrupted energy resources needed to deter all would-be aggressors and decisively engage in the full spectrum of conflict, particularly as it engages in a decades-long global war on terrorism. The question then becomes, how can the DoD contribute toward the President’s goal of creating a society which is not addicted to oil while simultaneously ensuring it has the energy and capabilities to complete its mission?

Mankind’s long-term supply of petroleum fuel is threatened by a phenomenon known as Hubbert’s Peak—that point in time when the production of oil reaches a maximum, and then declines steadily thereafter. The debate about when the world will reach its Hubbert’s Peak has raged for decades, with many credible

Article Highlights

An uncertain world energy prospect, a vital national defense mission, and the unique organizational capacity and situation of the DoD invites one to ask if an opportunity exists for the DoD to serve as an example for a national transformation toward a new energy future.

"War Without Oil: Catalyst for Transformation" via the application of the first three steps of Dr John P. Kotter's eight-step process for leading organizational change, proposes a method by which the Department of Defense (DoD) can lead an immediate, coherent, and viable long-term strategy toward a vision of replacing petroleum as its primary energy source in order to maintain all necessary strategic and operational capability for US security to 2050 and beyond. According to the author, the first step is to create a sense of urgency within the DoD that its long-term existence is threatened by rising energy costs and the prospect of declining energy supplies. The second step is to create a guiding coalition in the form of an Office for the Undersecretary of Defense for Assured Energy that possesses both the internal and interagency authority and the singular purpose necessary to lead a 45-plus year energy transformation process. Consisting of permanent representatives from OSD, the Services and interagencies, as well as representatives of industry and academia, this group must develop and communicate the vision of a desired energy future it wishes to create. Finally, by working backwards from that desired end state, the team must then build, communicate, and execute an overarching strategy that subdivides this grand challenge into a continuum of manageable short-term goals.

Using the hypothetical vision of a 2050 US military unconstrained by conventional paradigms, this article proposes a three-stage transformation strategy to

sources predicting dates which have already passed, others predicting dates within the next decade, and others proclaiming there will never be a peak. This discussion recently intensified when ExxonMobil, the world's largest oil company, achieved record profits of \$36B in 2005⁶ on all-time-high oil prices, but also quietly predicted in that same year that world oil production in non-Organization of Petroleum Exporting Countries (OPEC) would peak within 5 years.⁷ If this prediction is, in fact, true, the potential global geopolitical and economic consequences could be profound. Consider the effects Hurricane Katrina and Iranian *nuclear brinkmanship* have demonstrated on an 84 million barrel-per-day world oil market,⁸ in which two-thirds of all reserves reside in the Middle East.⁹ In addition, the growth of emerging economies will push global demand to within 98 percent of available production capacity.¹⁰

If the US were ever forced to rely upon domestic petroleum supplies exclusively, it only possesses enough indigenous reserves to meet 2005-level demand for 4 to 5 years (equal to 2 percent of global reserves which includes Alaska National Wildlife Refuge supplies).¹¹ The President is correct in proclaiming that technology will be necessary to break America's addiction to oil. Another strong proponent of technology is the DoD, which has embraced its benefits as a key enabler for strategic, operational, and tactical success—a concept validated by the swift combat victories in Kuwait, Afghanistan, Iraq, and Bosnia over the last 15 years. However, the demand for increasingly more complex high-technology systems has placed the DoD at the end of increasingly long acquisition cycles, of which the 20-plus year development of the F-22A Raptor is a perfect example. It is precisely the long acquisition lead times of these petroleum-fueled weapon systems, in conjunction with their decades-long life cycles (for example, the 45-year-old B-52 fleet), that will uniquely force the DoD to be the first government agency to address an approaching global oil peak.

The Department has already felt the impacts of a tight oil supply over the past 2 years. Increased global demand and Hurricane Katrina-induced shortages doubled the price of a barrel of oil from \$36 in 2003 to \$73 by 2005, forcing the DoD to redirect nearly \$3B of its fiscal year (FY) 2005 budget to cover the cost of fuel to the detriment of other programs.¹² This budgetary *pain* has caused every Service to form senior-level focus groups aimed at exploring and implementing various approaches to reduce the Department's fuel burden. Proposals range from promoting conservation efforts, expanding the use of renewable energy for base support, intensifying turbine engine efficiency research, and even establishing an independent DoD oil shale-to-synthetic fuel industry. While actionable, these various strategies appear to be occurring relatively independently within the DoD, absent an official grand vision or long-term, overarching strategy to move the DoD beyond petroleum as the President has asked America to do. This condition also appears representative of the competition among future energy strategies vying for dominance in American society at large.

An uncertain world energy prospect, a vital national defense mission, and the unique organizational capacity and situation of the DoD invites one to ask if an opportunity exists for the DoD to serve as an example for a national transformation toward a new energy future. Based upon the first three elements of Dr John P. Kotter's popular eight-step model for organizational

transformation, this article presents a methodology for determining if the DoD can lead an immediate, coherent, and viable long-term strategy toward a vision of replacing petroleum as its primary energy source in order to maintain all necessary strategic and operational capability for US security to 2050 and beyond.

The three-part approach begins in the first section by scoping the dimensions of the American energy security problem to create a sense of urgency. It continues in second section by examining the method in which an assured energy-guiding coalition and a DoD grand energy vision can be formulated within the context of the specific security responsibilities and desired capabilities of the DoD, as well as responsibilities of the DoE. The methodology finishes in the third section by highlighting the process by which a grand strategy can be developed that supports a new DoD energy vision. While there are a multitude of possible and competing DoD energy visions suitable for separate debate, the analysis in this article is accomplished under the structure of a conceptual three-phase hydrogen- and electric-based military transformation strategy that supports a 2050 post-petroleum vision aligned with President Bush's State of the Union goals.

If the above methodology demonstrates a feasible approach for guiding the DoD energy transformation to serve the Department's own requirements, it can then be argued that the lessons learned and knowledge gained from such an endeavor could be applied toward a larger national energy transformation. The DoD-to-civilian transition model has been successfully applied in other major societal changes to include racial integration, sexual equality, and the benefits of networked-based information sharing (Arpanet/Internet) to highlight a few. The creation of a broadly supported post-petroleum DoD vision and transformation strategy could not only preserve a relevant military force, but also lead a positive, bipartisan, interagency, and economic demonstration for preserving American security overall.

Creating a Sense of Urgency

The world is fast approaching the inevitable peaking of conventional oil production...(a problem) unlike any yet faced by the modern industrialized society.

—Feb 2005 DoE Report, Washington, DC¹³

The Big Picture

Two hundred million years ago the foundations of modern civilization were laid. Not only was it the evolution of man that gave us our world as we know it today, but also the life, death, and decay of nondescript vegetation, creatures, and microbes that would eventually become the 2 trillion barrels of crude oil man discovered and harnessed to write his modern history.¹⁵ How does one visualize 2 trillion barrels? Simple—the 76 cubic miles of oil man has ever discovered would fill a single tank just 5 miles across and less than 4 miles high—hardly the *Great Lakes* worth of oil that many may have imagined the Earth's petroleum reserves to be. That 5-mile tank would fit nicely inside the 10-mile boundaries of Washington, DC and rise to an altitude of just 20,500 feet—an elevation equal to half of a typical passenger jet's cruising altitude, or no more than 37 Washington Monuments (555 feet each) stacked one atop another (see Figure 1). Now consider the most dramatic visualization: based upon a widely accepted model of peak oil

Article Highlights

illustrate the incremental issues that will likely present themselves in a wholesale energy transformation. Stage I (2006–2020) includes undertaking conservation, efficiency, acquisition, and organizational reforms; the development of bridging energies; massive research and development (R&D) efforts; the establishment of *new energy* standards; and identification of a primary alternate energy source most likely to be some combination of electricity and hydrogen produced from a variety of sources. Stage II (2020–2035) focuses on adjusting force structure, adjusting operational and training procedures, and creating a distributed energy infrastructure and technology transition in a modular fashion. Stage III (2035–2050) involves finishing infrastructure conversion; ensuring adequate, distributed, and ubiquitous energy production; and a continuation of R&D energy efforts.

Article Acronyms

AEI - Advanced Energy Initiative
ARPA-E - Advanced Research Project Agency-Energy
DARPA - Defense Advanced Research Projects Agency
DESC - Defense Energy Support Center
DoD - Department of Defense
DoE - Department of Energy
DSB - Defense Science Board
EIA - Energy Information Agency
EPFO - Energy Power and Fuels Office
EPTI - Energy and Power Technologies Initiative
FT - Fischer-Tropsch
ISR - Imagery, Surveillance, and Reconnaissance
LED - Light-Emitting Diode
KPP - Key Performance Parameters
NAS - National Academy of Sciences
NDS - National Defense Strategy
NRAC - Naval Research Advisory Committee
NSS - National Security Strategy
O&M - Operations and Maintenance
OPEC - Organization of Petroleum Exporting Countries
OSD - Office of the Secretary of Defense
PPBS - Planning, Programming, and Budgeting System
QDR - Quadrennial Defense Review
R&D - Research and Development
USD - Under Secretary of Defense

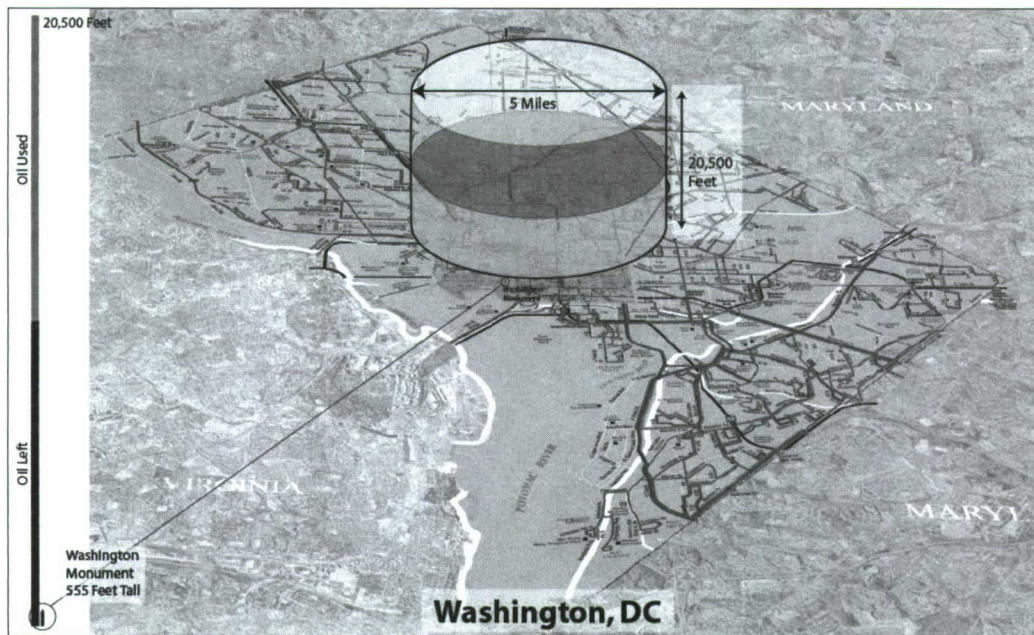


Figure 1. The Big Picture¹⁴

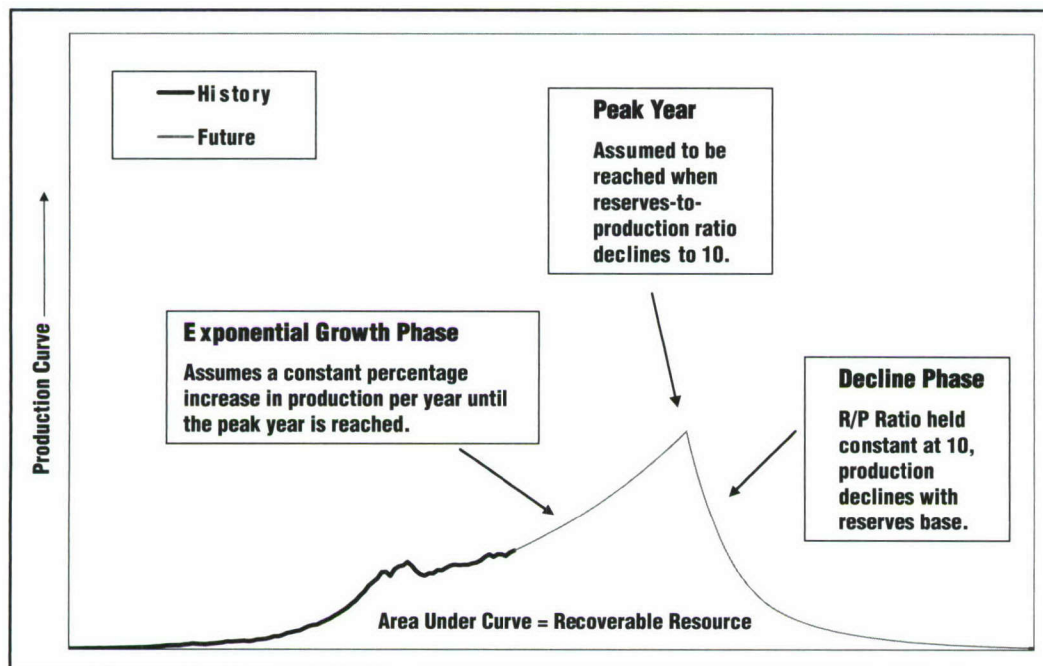


Figure 2. EIA's Model for Conventional Oil Resources¹⁷

Top 10 Petroleum Producers				
Rank	Country	M bbl/Day Produce	M bbl/Day Export	% World
1	Saudi Arabia	10.4	8.7	12
2	Russia	9.3	6.7	11
3	United States	8.7	-	10
4	Iran	3.8	2.6	5
5	Mexico	3.6	1.8	4
6	China	3.2	-	4
7	Norway	3.2	2.9	4
8	Canada	3.1	<1.0	4
9	Venezuela	3.1	2.4	4
10	UAE	2.8	2.3	3

Table 1A. 2004 Top 10 Petroleum Producers²²

production known as Hubbert's Peak, many world petroleum geologists believe that by 2020 traditional global oil production will reach a maximum,¹⁶ followed by a predictable and potentially very rapid decline as depicted by the Department of Energy's Energy Information Agency (EIA) in Figure 2.

Complicating the matter is a lack of professional consensus on the actual expected date of global peak oil production, with credible organizations such as ExxonMobil predicting that the non-OPEC (Organization of Petroleum Exporting Countries) Hubbert's Peak will arrive within 5 years,¹⁸ and the US government claiming the planet's absolute peak will occur somewhere around 2037, the midpoint of an officially estimated 45-year window (see Figure 3).

What cannot be disputed is that since the first drop of oil was discovered in 1859, 920 billion²⁰ of the Earth's 2.001 trillion barrels²¹ in proven conventional petroleum have been consumed with activities such as building homes, growing food, producing plastic packaging, creating industries, running to the corner video rental store, and waging wars. There is now only one question left to answer—with a depth of only 20 Washington Monument-equivalents left, is the tank that remains half full, or is it half empty?

Global Oil Supply and Demand

Each day mankind consumes approximately 84 million barrels of oil exchanged through a global commodities market that maintains a supply and demand equilibrium through the fluctuations of a single trade price.²³ An immediate observation from Tables 1A and 1B is that Saudi Arabia and Russia occupy the number 1 and number 2 producer positions ahead of the United States, and that of the top 10 producer countries listed, only Mexico, Norway, and Canada can be considered strategically reliable sources for the US. Furthermore, among the major consumers, only Russia, Canada, and Brazil are petroleum self-sufficient. This imbalance highlights the fact that the majority of nations rely upon some form of petroleum imports to

Top 10 Petroleum Consumers				
Rank	Country	M bbl/d	M bbl/Day Import	% World
1	United States	20.7	12.1	24
2	China	6.5	2.9	8
3	Japan	5.4	5.3	6
4	Germany	2.6	2.4	3
5	Russia	2.6	-	3
6	India	2.3	1.5	3
7	Canada	2.3	-	3
8	Brazil	2.2	-	3
9	South Korea	2.1	2.1	3
10	France	2.0	1.9	2

Table 1B. Top 10 Petroleum Consumers²²

satisfy domestic energy needs; for example, the US imports 53 percent of daily demand (25 percent of which comes from OPEC, with 60 percent of that amount imported from Saudi Arabia), China 44 percent, Germany 93 percent, and Japan, South Korea, and France import virtually all of their oil.²⁴ The top 15 US oil suppliers are shown in Table 2.

While the US is the third leading oil producer, it does not enjoy a podium position when it comes to known oil reserves—a much greater measure of long-term energy vulnerability. Figure 4 depicts global oil reserve distribution. Canada's 178 billion barrels include 4.3 billion barrels of conventional crude and 174 billion barrels of synthetic oil to be potentially derived from tar sands.²⁶

Saudi Arabia's 262 billion barrels, together with OPEC's additional 449-plus billion barrels, represent 68-plus percent of known oil reserves.²⁸ Russia, Venezuela, and Nigeria together control the next major share, at 14 percent.²⁹ What this means for the US, which possesses only 2 percent of the world's reserves (including Alaska National Wildlife Reserves), is that if it were forced to consume only domestic oil starting tomorrow, pumping the additional 4 billion barrels a year over current levels would deplete the country's supplies within 4 to 5 years.³⁰ Most of America's declared allies would last only months on internal reserves. The simple consequence is that because Western economies depend on foreign oil, today the US and its

Rank	Country	Crude Oil	Products	Total
1	Canada	1,616	522	2,138
2	Mexico	1,598	66	1,665
3	Saudi Arabia	1,495	63	1,558
4	Venezuela	1,297	258	1,554
5	Nigeria	1,078	62	1,140
6	Iraq	655	1	656
7	Algeria	215	237	452
8	United Kingdom	238	142	380
9	Virgin Islands	0	330	330
10	Angola	306	10	316
11	Russia	158	140	298
12	Kuwait	241	9	250
13	Ecuador	232	13	245
14	Norway	143	101	244
15	Colombia	142	34	176
	Total	10,088	3,057	13,145
	Persian Gulf	2,400	93	2,493

Table 2. Top Suppliers of US Crude Oil and Petroleum, 2004 (Thousand Barrels per Day)²⁵

Published	By	Peak Year/Range	Published	By	Peak Year/Range
1972	ESSO	About 2000	1999	Parker	2040
1972	UN	By 2000	2000	Bartlett	2004 or 2019
1974	Hubbert	1991-2000	2000	Duncan	2006
1976	UKDOE	About 2000	2000	US DoE/EIA	2021-2167; 2037 most likely
1977	Hubbert	1996	2000	IEA (WEO)	Beyond 2020
1977	Ehrlich, et al.	2000	2001	Deffeyes	2003-2008
1979	Shell	Plateau by 2004	2001	Goodstein	2007
1981	World Bank	Plateau by 2004	2001	Smith	2010
1985	Bookout	2020	2002	Campbell	2010
1989	Campbell	1989	2002	Cavallo	2025-2028
1994	Ivanhoe	OPEC Plateau 2000-2050	2003	Greene, et al.	2020-2050
1995	Petroconsultants	2005	2003	Laherrere	2010-2020
1997	Ivanhoe	2010	2003	Lynch	No visible peak
1997	Edwards	2020	2003	Shell	After 20205
1998	IEA (WEO)	2014	2003	Simmons	2007-2009
1998	Campbell Leherrere	2004	2004	Bakhtari	2006-2007
1999	Campbell	2010	2004	CERA	After 2020
1999	Odell	2060	2004	PFC Energy	2015-2020

Figure 3. Thirty-Six Estimates of the Time of Peak World Oil Production¹⁹

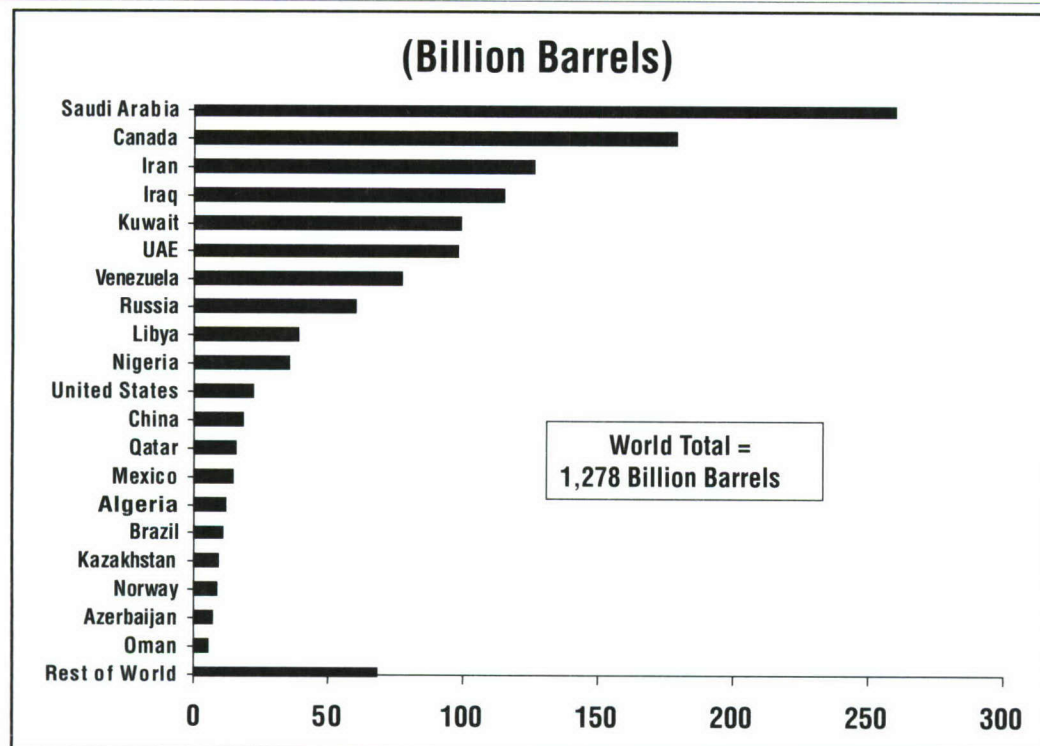


Figure 4. Proven World Oil Reserves²⁷

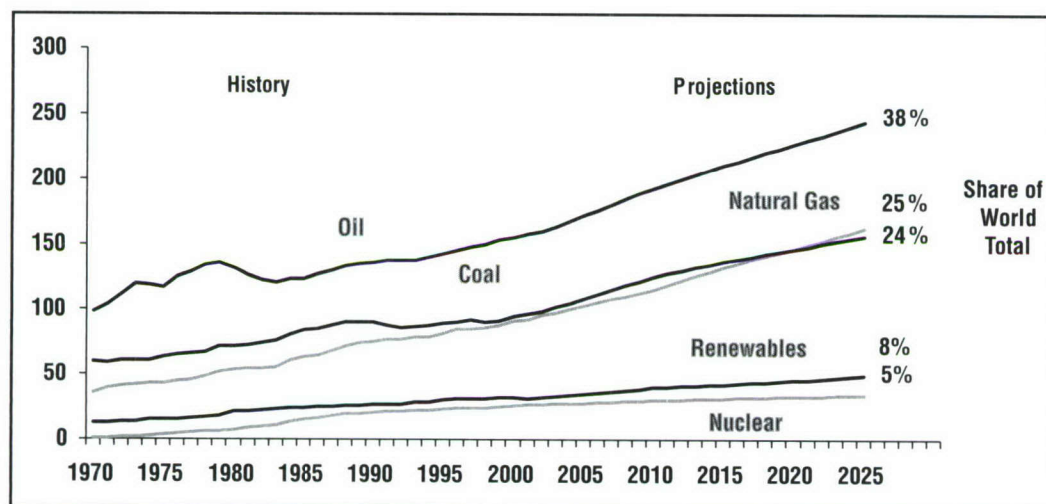


Figure 5. Worldwide Energy Consumption by Fuel Type³⁶

allies cannot unilaterally control their own economic and physical securities.

Global reserve figures fluctuate with the discovery of new oil fields and extraction technologies—an activity directly related to the profitability of each barrel of oil. Easily discovered and recovered oil is produced first, while more difficult sites are only identified or developed when technically and financially feasible. This basic condition leads to a reduction in discoveries over time. The fact that 80 percent of today's oil reserves were discovered before 1973 supports this simple model.³¹ Additionally, reserves are being depleted at three times the discovery rate,³² and since 2000 the cost of finding and developing new oil sources has risen about 15 percent annually.³³

Possessing accurate international reserve data is extremely important in the development of national security strategy—it defines acceptable near- and long-term energy dependence risks,

when combined with projected population growth patterns, reveals a first-of-its-kind event in human history. Emerging economies will overtake the energy needs of economically mature and transitional economies (such as former Communist countries) by 2020, with potentially profound sociopolitical consequences for the world (see Figure 6).

Energy Implications for America

This type of mushrooming, emerging-economy demand elevates prices and precisely collides with a growing US demand for imported oil. US demand is expected to grow by 37 percent (1.5 percent per year) in the next 20 years to a total of 27.9 million barrels per day in 2025, at which point the nation will be importing 68 percent of its oil.³⁸ The EIA chart in Figure 7 most clearly illustrates America's expected oil future.

What are the consequences of this situation for the US military? First, as the world's largest single oil consumer, the

international relationships, and economic and military structures for each nation on Earth. Herein lies great uncertainty, in that many countries withhold reserve information or may actually inflate values to obtain economic or diplomatic leverage. The obvious conclusion is that public world oil reserve prediction is both an imprecise art and a science, encouraging prudence when it comes to performing national security calculations.

Reserve data itself only becomes meaningful when applied against projected consumption rates (see Figure 5). DoE's EIA tracks, analyzes, and predicts global energy supply and demand. EIA administrator Guy Caruso predicted that,

Worldwide energy consumption will grow by 57 percent between 2002 and 2025, at an average annual growth rate of 2 percent, with the strongest growth in the emerging economies, particularly in Asia.³⁴ World oil demand will grow from 78 to 119 million barrels per day, with the United States and emerging Asia, including China and India, accounting for 64 percent of the growth.³⁵

As a result of globalization, the ability of individuals in emerging economies (such as China) to rapidly improve their quality of life has exploded in the last 10 years. This trend,

DoD will pay significantly more to sustain its daily operations. Whereas the temporary 1973 and 1980 energy crises were politically motivated, OPEC-engineered supply shortages that self-corrected after world demand constricted and non-OPEC suppliers expanded production, the 2005 energy situation appears semipermanent, with global demand essentially equaling available global production capacity. EIA reported that, in 2005, surplus global oil production capacity was only 1.5 million barrels per day, less than 2 percent above the daily 84 million barrels/day demand.⁴⁰ Consequently, Goldman Sachs expects oil to remain at \$60-plus a barrel for at least the next 5 years—indicating that a new oil equilibrium in world oil prices has been reached.⁴¹ Acute regional crises such as another Gulf Coast Katrina-style weather event, a terrorist destruction of the 5 million barrels per day Saudi Ras Tanura petroleum processing facility,⁴² or a UN-sponsored embargo of Iran could also temporarily drive the price of oil to as high as \$131 per barrel, according to Mr. Zarocostas.⁴³ The second and greater significance of a permanently tightening global energy market is that, precisely when the energy cost of national security is rising, by 2025 the DoD's activities and America's foreign policy could be ever more dictated by the requirement to secure the 68-plus percent share of oil it needs to acquire internationally.

The simple fact is that America's (and the world's) economic and physical health are dependent upon a fragile oil lifeline. While this system is so distributed that it would be virtually impossible to ever destroy it in its entirety, the evaporation of excess global production capacity in the past decade ensures that any major disruption (2 million barrels per day or more) in one area, cannot be compensated for by increasing production in another. It is important to understand how the US economy and military depend upon oil so that when shortages do occur, military leaders are knowledgeable about the challenges they will face.

The major end use for oil in the US should be a surprise for no one—transportation. Figure 8 from *Winning the Oil Endgame* best describes this situation. In 2000, America consumed approximately two-thirds of its 19.7 million barrels of oil per day for all forms of transportation—by 2025 this percentage is

expected rise to 73 percent of a total 28.3 million barrels per day consumption rate (see Figure 9).⁴⁴

These statistics reinforce the observation that it is difficult to replace petroleum-based fuels as a source of mobility for American society—the combination of relatively low production cost and high energy density make it very attractive for this purpose. Mobility allowed America to take advantage of its natural resources, entrepreneurial spirit, and intellectual capacity to become the world's economic and military leader. In addition to transportation uses, the remaining one-third of petroleum powers America's industrial engine, heats and electrifies its buildings, and most importantly, forms the industrial feedstock to produce a wide variety of organic compounds, the most significant of which is the family of plastics and fertilizers.

DoD Energy Dependencies

In addition to the direct consumption of petroleum to power combat systems, there are four under-recognized DoD petroleum dependencies.

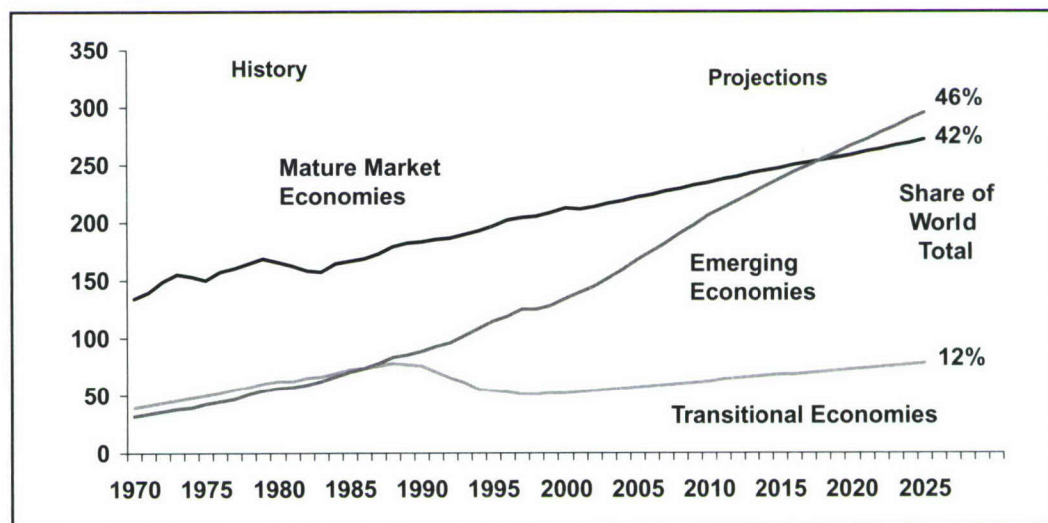


Figure 6. World Energy Consumption by Region³⁷

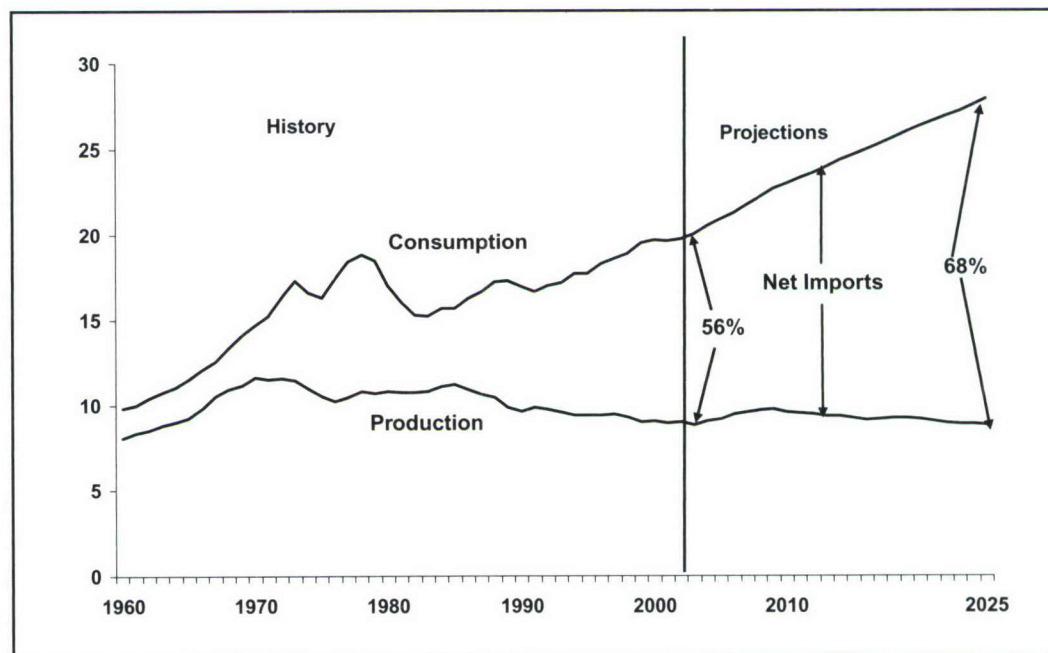


Figure 7. US Petroleum Supply, Consumption, and Imports³⁹

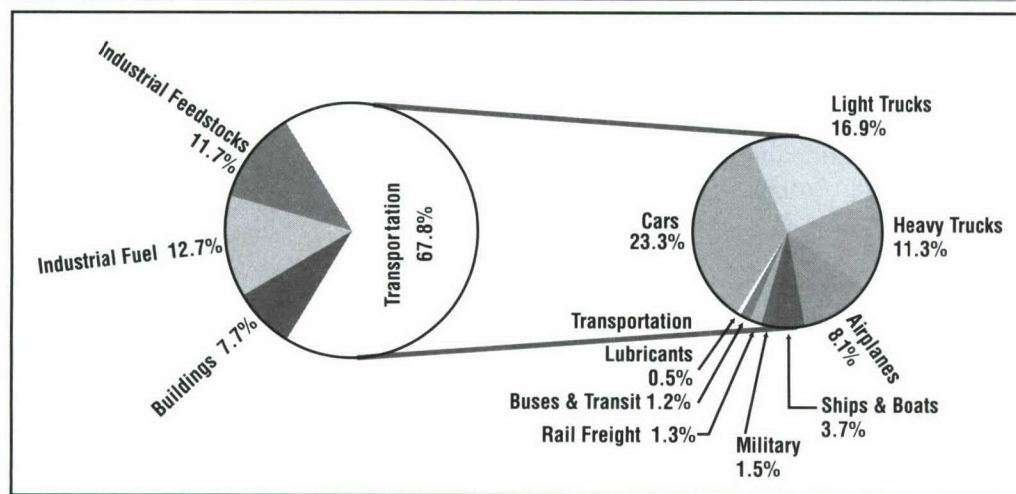


Figure 8. 2000 US Oil End Use ⁴⁵

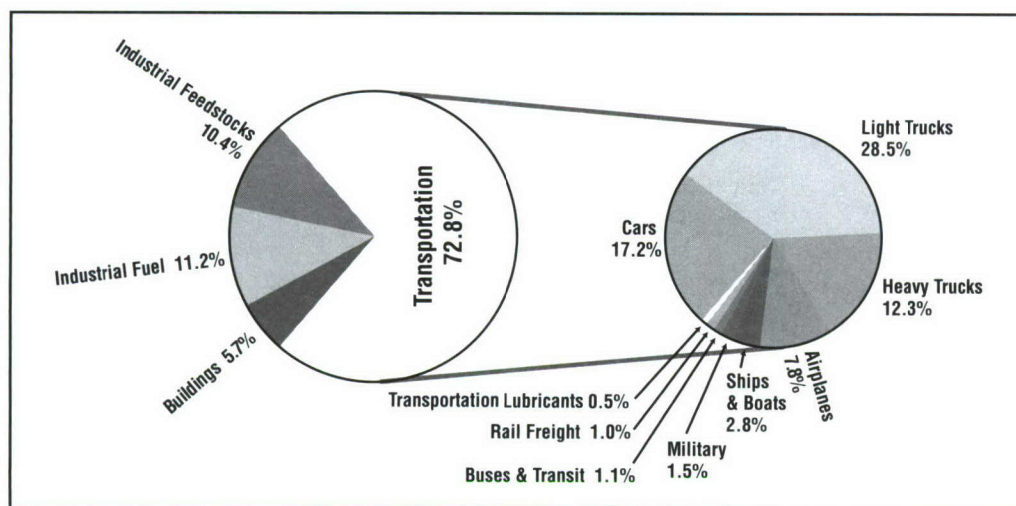


Figure 9. 2025 US Oil End Use ⁴⁶

- Military industrial supply
- Contractor support
- Commercial logistics
- Installation requirements

While studying DoD petroleum dependencies, most policymakers and analysts will focus on the 1.8 percent of national petroleum consumption directly used by the DoD (94 percent of which is for mobility and transportation).⁴⁷ This approach ignores the indirect dependencies of a highly intertwined military-industrial complex necessary for modern high-technology warfare. While it may be virtually impossible to quantify and categorize the amount of petroleum specifically required to create and support every activity or procured end item within the DoD, the fact that the DoD relies upon an industrial base for medical syringes, M-16s, and C-17 parts serves to illustrate that the DoD is just as reliant upon petroleum-fueled civilian and governmental institutions as the rest of American society. Recognizing the fact that fueling national defense goes beyond just the direct use of petroleum by armed forces and into a much deeper supply chain dependency is fundamental to understanding the vulnerability of America's security to strategic petroleum supply disruptions or declines.

This military/industrial dependency necessarily links civilian and military future energy solutions.

The second under-recognized DoD petroleum dependency exists in the realm of increasingly ubiquitous contractor support. The DoD relies upon service contractors to fulfill a broad spectrum of requirements ranging from base maintenance to military interrogations. With the exception of DoD-provided combat zone fuel, the vast majority of DoD service contracts expect the contractor to independently acquire all fuels necessary to fulfill his obligations. These requirements are not represented on DoD total fuel tally sheets, and represent a potential problem for military leaders should their contractors ever be unable to purchase fuel during a strategic or even operational energy shortage or crisis.

The third under-recognized DoD petroleum dependency is in commercial logistics. The DoD possesses one of the greatest organic mobility fleets in the world, for which the Defense Energy Support Center (DESC) and Service fuel managers diligently supply and track fuel usage. What is often ignored in determining

total national security energy requirements, however, is the fuel required to transport military supply chain materials within the industrial production cycle and then from the factory to the point of military possession. Similarly, fuel used by contract commercial air carriers, Civil Reserve Air Fleet participants, and oceanic shippers to shuttle DoD personnel and material to and from deployments or on routine business does not receive an entry on military fuel balance sheets. While it is virtually impossible to precisely tabulate the amount of transportation fuel used by the civilian sector to support the DoD, it is accurate to say that some non-negligible civilian portion of the 67.8 percent of US oil used for transportation in Figures 8 and 9 is used to directly or indirectly support DoD operations.

The final under-recognized defense petroleum dependency is in installation requirements. While most permanent US military installations rely upon commercially purchased coal- or natural gas-fueled electricity or heat, expeditionary bases rely upon petroleum-fueled organic power production because of their temporary nature and high security requirements. Today's increasingly electrified forces demand large quantities of uninterrupted power to support critical garrison, command and control, and expeditionary functions. Even where reliably safe commercial electrical power is available in the US, mission-

critical functions utilize diesel back-up generators to guarantee uninterrupted power. The implication then is that any DoD future energy strategy must also address how to provide installation power in a petroleum-constrained environment, whether it is in an austere forward deployed location, or in the US after a natural gas *Hubbert's Peak* (EIA expects US domestic natural gas production to peak in 2015).⁴⁸ As will be discussed later in this article, the similarities between permanent base energy requirements and their civilian institutional counterparts provide the DoD with a double opportunity to immediately leverage commercial advances against installation energy vulnerabilities and then to apply this same process toward solving more demanding expeditionary base energy vulnerabilities.

Having explored the four under-recognized forms of DoD petroleum dependence and vulnerability, the more obvious question can now be asked, "how much and in what way does DoD depend upon petroleum to directly complete its combat mission?" Few would disagree that combat is one of the most energy intense activities known to man. The military depends on oil to provide agility, global power projection, and focused logistics.⁴⁹ It must also be able to rapidly produce and sustain these effects in maximum performance scenarios, under broad climate extremes, and in hostile fire situations—criteria for which petroleum fuels are typically well suited. The two most recent US military operations serve as perfect examples of the fuel required to sustain decisive combat activities. In its Fiscal Year 2004 Fact Book, the Defense Energy Support Center (DESC) reports that between October 2001 and September 2003, Operation Enduring Freedom required 2.6 million gallons (61,500 barrels) of fuel a day. Between March 2003 and September 2004, Operation Iraqi Freedom consumed 1.06 million gallons (25,300 barrels) per day.⁵⁰

Reviews of American military doctrine over the last 60 years reveal a heavy emphasis on airpower as either a stand-alone strategic instrument, or as a complement to ground forces that can gain, achieve, and then exploit air superiority to maximize terrestrial opportunities. Airpower leverages inherent surprise, maneuverability, mobility, and the ability to amass firepower to overwhelm an enemy, and reduce the risk to one's own forces. This American-perfected and synergistic air-land dominance comes at a great energy cost. By studying the DESC *FY04 Fact Book*, one can identify some force structure vulnerabilities that would quickly manifest themselves, should the US military ever find itself in a strategically or operationally constrained petroleum environment. The first clue can be found in the breakdown of total fuels used in DoD. Accounting for \$5B of the Department's \$437B FY04 budget, DESC procured 134 million barrels of liquid fuel (370,000 barrels per day), of which 75 percent (101 million barrels) were some form of aviation fuel (JP-4, JP-5, JP-8, or Jet A).⁵¹

By combining the Air Force's \$2,841M bill with the \$722M JP-5 portion of the Navy's \$1,627M bill,⁵³ and other smaller Army and Marine Corps amounts, Table 3 reveals that in fact 75 percent of the DoD's petroleum purchases went to fuel aircraft and some ships, with the Air Force accounting for 57 percent of the total DoD bill in FY04.⁵⁴ Deeper analysis reveals that of the Air Force's \$2.8B aviation fuel bill, 54 percent went to mobility air forces, 38 percent went to combat air forces, and the remaining 8 percent was consumed by aircrew training and other aviation

operations.⁵⁵ The fact that 8 of 10 entries on DESC's list of Top Ten Customers for FY04 are air mobility bases⁵⁶ seemingly confirms that air mobility (airlift and air refueling) is the single most petroleum-intense activity within the DoD, making focused logistics and dominant maneuver the most energy-vulnerable dimensions within the DoD's vision of full spectrum dominance for *Joint Vision 2025*.

It is at this point that operational commanders and future force planners should take note of the petroleum dependencies of their systems and contemplate the loss of combat power or force multipliers during hypothetical conditions of extreme fuel constraint (conceivably created by asymmetrical attack, large-scale fuel contamination, or limited future global availability). Taking a quick scroll through today's weapon systems inventory, it is not unreasonable to visualize that in the hypothetically extreme case of 100 percent expeditionary fuel nonavailability, only nuclear submarines (nuclear aircraft carriers are relatively useless without jet fuel), missile forces, space forces, cyber forces, and certain self-sufficient special operations forces could likely operate in a petroleum-free environment. In the case of a 75 percent severely constrained petroleum environment, perhaps only light infantry that could *live off the land* would be persistent. In a 50 percent, medium-fuel-constrained environment, sea shipping, light-medium ground forces, and some limited range combat air support might be available. In a 25 percent, mildly constrained-fuel environment, the greatest shortfall would likely be in air mobility, followed by combat air support (a potential issue for a US Army that has committed to reducing field artillery in exchange for reliance on air power to provide indirect fire effects). The only way to be scientifically confident of the impact that various levels of fuel constraint would place upon US operational forces would be to conduct a purpose-built modeling simulation that specifically asks this question—an endeavor that sources, polled by this author, indicate has not yet occurred⁵⁷. This capabilities drill demonstrates that the effectiveness of necessary *JV2025* dominant maneuver, focused logistics, precision engagement, full dimension protection, and information security concepts will be dependent upon the force structure and energy security decisions DoD policymakers elect to make today.

The National Security Strategy

Before setting out to create a future energy vision and strategy for the DoD, it is important to understand America's vision for its future security and credible threats to it, develop the best grand strategy to counter those threats, and then analyze how dependent that strategy is upon known and projected energy supplies so that adjustments can be made if necessary. The National Security Strategy (NSS) is the President's cornerstone document for articulating America's perceived threats and how he expects to protect the nation's interests. The NSS provides broad strategy for both near- and long-term threats, while

Service	Air Force	US Navy	US Army	US Marine Corps
Fuel Purchased (\$ millions)	\$2,841	\$1,627	\$440	\$23

Table 3. FY04 DoD Fuel Purchases by Service⁵²

enabling subordinate documents such as the DoD's *National Defense Strategy* (NDS) and the Chairman of the Joint Chiefs of Staff's *National Military Strategy* to identify ever more detailed approaches for converting strategy into actionable security. Examining these documents provides a framework within which to study America's future defense requirements and how they relate to the subject of assured energy.

In his NSS President Bush acknowledges that,⁵⁸

Defending our Nation against its enemies is the first and fundamental commitment of the Federal Government. Today, that task has changed dramatically. Enemies in the past needed great armies and great industrial capabilities to endanger America. Now, shadowy networks of individuals can bring great chaos and suffering to our shores for less than it costs to purchase a single tank. Terrorists are organized to penetrate open societies and to turn the power of modern technologies against us.⁵⁹

America is now threatened less by conquering states than we are by failing ones. We are menaced less by fleets and armies than by catastrophic technologies in the hands of the embittered few. We must defeat these threats to our Nation, allies, and friends.⁶⁰

We are guided by the conviction that no nation can build a safer, better world alone. The United States is committed to lasting institutions like the United Nations, the World Trade Organization, the Organization of American States, and the North Atlantic Treaty Organization, as well as other long-standing alliances.

To achieve the goals of political and economic freedom, peaceful relations with other states, and respect for human dignity, the strategy of the United States is to:⁶¹

- Champion aspirations for human dignity
- Strengthen alliances to defeat global terrorism and work to prevent attacks against us and our friends
- Work with others to defuse regional conflicts
- Prevent our enemies from threatening us, our allies, and our friends, with weapons of mass destruction
- Ignite a new era of global economic growth through free markets and free trade
- Expand the circle of development by opening societies and building the infrastructure of democracy
- Develop agendas for cooperative action with other main centers of global power
- Transform America's national security institutions to meet the challenges and opportunities of the twenty-first century

These NSS excerpts imply the following tasks for the DoD:

- Be prepared to cooperate with friends and allies to prevent weapons of mass destruction or other attacks
- Be prepared to help diffuse regional conflicts
- Protect the foundations of free markets and trade
- Be prepared to transform to meet the challenges and opportunities of the 21st century

In essence, these strategic defense responsibilities become the DoD's mission—how well these tasks are accomplished becomes the standard of performance against which any present or future force will be measured, regardless of whether it is petroleum or alternatively fueled. It is an ongoing responsibility of force structure planners to create a capable and relevant force not only for today, but to 2050 and beyond.

Before creating a defense energy strategy from the NSS, it would also be prudent to incorporate the President's guidance with regard to strategic energy security. On this matter the NSS states:⁶²

We will strengthen our own energy security and the shared prosperity of the global economy by working with our allies, trading partners, and energy producers to expand the sources and types of global energy supplied, especially in the Western Hemisphere, Africa, Central Asia, and the Caspian region. We will also continue to work with our partners to develop cleaner and more energy-efficient technologies.

And under the strategy for reducing carbon dioxide emissions to slow global warming, the NSS promotes:⁶³

- Renewable energy production and clean coal technology, as well as nuclear power—which produces no greenhouse gas emissions, while also improving fuel economy for US cars and trucks
- Increasing spending on research and new conservation technologies, to a total of \$4.5B—the largest sum being spent on climate change by any country in the world and a \$700M increase over last year's budget

While the NSS does not appear to directly discuss the risk of a growing reliance on increasingly scarce foreign energy, the President's 2006 State of the Union Address updates this concept by elevating the security imperative of eliminating foreign energy dependence.⁶⁴

The National Defense Strategy

The DoD is the primary organization charged with ensuring America's external physical security. The Secretary of Defense translates the President's NSS into a National Defense Strategy that guides DoD thought and action. The DoD's specific strategic objectives, as outlined in the NDS, are as follows.

- Secure the US from direct attack
- Secure strategic access and retain global freedom of action
- Strengthen alliances and partnerships
- Establish favorable security conditions⁶⁵

Force structure builders recognize that securing the US from direct attack requires possessing the means to do the following.

- Gather superior intelligence
- Deter and defend against identified threats
- Ensure uncontested movement on the seas, in the air, in space, and cyberspace
- Provide material assistance
- Directly aid a threatened friend while simultaneously satisfying the first two requirements
- Respond rapidly to world developments

To accomplish the objectives of assuring allies and friends, dissuading potential adversaries, deterring aggression and countering coercion, and defeating adversaries when necessary, the NDS implementation guidelines advocate the use of an active and layered defense, continuous transformation, a capabilities approach, and risk management to guarantee success.⁶⁶ This strategy is built upon several important assumptions.⁶⁷

- The US will retain a resilient network of alliances and partnerships.
- The US will have no global peer competitor and will remain unmatched in traditional military capability.
- The US will maintain important advantages in other elements of national power, such as political, economic, technological, and cultural.
- The US's capacity to address global security concerns alone will be insufficient.
- Natural forces of inertia and resistance to change will constrain military transformation.

The NDS unequivocally states that the US cannot achieve its defense objectives alone—the concept of active, layered defense includes international partners.⁶⁸ This admission and the assumption that the US will work through a network of alliances and partnerships necessarily dictates that any national defense and energy analysis must include the energy limitations or strengths of those aligned nations, many of which are significantly worse off than the US.

The US also assumes no current global peer competitor or traditional military equal. This is certainly the case in 2006, but it would be foolish to assume the same for 2050 since the US cannot unilaterally control the power rise of every nation on Earth—it can only control the level of effort it will expend to maintain its sole superpower position. Since superpowers typically seek to maintain their strength through various forms of innovation,⁶⁹ it is not unreasonable to assume the presence of technological advantages for the US—however, it is an assumption that can only be made if one also expects the rate of American innovation to exceed that of security competitors—another security concern raised by President Bush in his 2006 State of the Union Address.⁷⁰ Finally, the NDS strategy correctly recognizes that institutional inertia will act to resist the NSS's guidance to transform ahead of emerging threats.

Based on these assumptions, the NDS strategy for achieving an active, layered defense is to possess several key operational capabilities.⁷¹

- Protect critical bases of operation
- Operate from the global commons
- Project and sustain forces in distant, anti-access environments
- Improve proficiency against irregular challenges
- Increase capabilities of partners, international and domestic

These capabilities must exist so that when deterrence fails or efforts short of military action do not forestall gathering threats, the US can employ military power with other instruments of national power to *swiftly defeat* adversaries and achieve decisive, enduring results.⁷² In all cases the DoD plans to *seize the initiative and dictate the tempo, timing, and direction* of military operations.⁷³ Operational experience since 1990 also indicates that the DoD should no longer expect to fight in place, but rather it should *plan to surge from a global posture* to respond to crises.⁷⁴ The DoD's goal is to develop greater flexibility to contend with uncertainty by emphasizing agility and by not concentrating military forces in a few locations.⁷⁵ The US sees itself operating with *increasingly rotational forces* in four

forward regions: Europe, Northeast Asia, East Asian Littoral, and Middle East-Southwest Asia.⁷⁶

Using words such as *swiftly defeat*, *seize the initiative*, *surge from a global posture*, *emphasizing agility*, and *increasingly rotational forces* indicates that the US defense strategy relies heavily upon high-energy strategic mobility and operational and tactical maneuverability. The conclusion that can be drawn from this NSS and NDS review is that, to remain secure, the US will need to be both proactively engaged and ready to respond globally on a moment's notice against the full spectrum of threats—including nonwarfare events such as humanitarian crises and natural disasters. In 2006 the military capabilities providing this security are powered predominantly by liquid petroleum fuels. Acknowledging an uncertain global petroleum future and the uniquely energy-intense nature of modern warfare, the question then becomes, “How does the US envision the military force of 2050 to be reliably fueled and configured to provide the security America requires?”

Developing a Guiding Coalition and an Assured Energy Vision

By applying the talent and technology of America, this country can dramatically improve our environment, move beyond a petroleum-based economy, and make our dependence on Middle Eastern oil a thing of the past.

—President George W. Bush,
2006 State of the Union Address⁷⁷

Leading Change

In his popular book, *Leading Change*, renowned Harvard Business School professor John P. Kotter advocates an eight-step process for leading institutional change.⁷⁸

- Establish a sense of urgency
- Create a guiding coalition
- Develop a vision and strategy
- Communicate the change vision
- Empower employees for broad-based action
- Generate short-term wins
- Consolidate gains and produce more change
- Anchor new approaches in the culture

Dr Kotter's approach would seem to indicate that a structure exists to guide successful organizational transformation. While all eight steps are fundamental for creating lasting change, this article seeks to consider only the first three—establishing a sense of urgency, creating a guiding coalition, and developing a vision and strategy—as a basis for answering the question of whether the DoD can lead a long-term energy conversion vision and strategy in order to remain relevant to 2050 and beyond.

The first section of this article was intended to highlight the type of data necessary for generating a sense of urgency within the minds of policy decisionmakers. Acquiring a sense of urgency regarding any problem is a personal event, something strategic leaders must individually develop based on their perception of how facts and trends within a particular context might combine to negatively affect an organization's goals. Without a basic belief by senior leadership that an organization's

fundamental mission is at risk, it is likely that little, if any, transformation will result, regardless of the organization.

Once a senior leader believes that his organization's mission is threatened and that corrective action is warranted, Kotter suggests that the next step is to form a guiding coalition that will develop a vision and a strategy toward a better future.⁷⁹ Building upon the previous chapter's presentation of energy data, NDS assumptions, and required key operational capabilities, this section examines a methodology in which senior defense leaders could conceptually assemble an effective guiding coalition responsible for creating the vision of defense energy transformation. According to Dr Kotter, the strong coalition is necessary:

Because major change is so difficult to accomplish, a powerful force is required to sustain the process. No one individual, even a monarch-like leader, is ever able to develop the right vision, communicate it to large numbers of people, eliminate all of the obstacles, generate short-term wins, lead and manage dozens of change projects, and anchor new approaches deep in the organization's culture. A strong guiding coalition is always needed—one with the right composition, level of trust, and shared objective.⁸⁰

Furthermore, building a coalition that can make change happen requires finding the right people, creating trust among them, and then allowing them to develop a common goal.⁸¹ Bottom line: a guiding coalition must function as a championship team.

The first step in forming a winning assured energy team is to include representatives of the major elements inside and out of the DoD who would play a fundamental role or be fundamentally affected by an energy transformation. The list would include such easy choices as highly motivated strategic leaders in the operations, plans, and logistics communities, the science and technology research and development community, the acquisition community, and leaders of individual Service energy senior focus groups. Less obvious might be the public affairs community needed to effectively market an energy vision and transition strategy, the budget and programming community to advise and execute programming decisions, and representatives of key agencies such as the Department of Energy, the National Science Foundation, or the Environmental Protection Agency to provide specific expertise. These members would all serve in full-time positions, while additional expertise could be provided through outside consultations or partnerships with industry and academia.

Because of the potentially profound department-wide scope that an energy transformation could entail, and the typical institutional resistance to transformational change acknowledged in the first section's review of NDS assumptions, the guiding coalition would need to occupy a position of significant authority within the organization such that coalition decisions could be sufficiently respected and executed within all elements of the Department. Such authority is best exercised in close proximity to the strategic leader forming the guiding coalition, which in this case would mean an office no less than that of an undersecretary.

Creating the Office of Assured Energy

Proposing a high-level agency to lead energy transformation is not without precedence. In a December 2005 predecision proposal to Dr Theodore Barna, Assistant Deputy Undersecretary

Defense/Advanced Systems and Concepts recommended that the DoD establish an Energy, Power, and Fuels Office (EPFO), composed of Service, OSD, and interagency representatives to lead a multifaceted approach (called the Assured Fuels Initiative) for military energy security focused primarily on synthetic fuels production.⁸² This EPFO represents the type of *guiding coalition* that Dr Kotter recommends. However, by broadening the scope of Dr Barna's proposal beyond synthetic fuels to include all forms of military energy, it may be advantageous to elevate the EPFO synthetic fuels office that Dr Barna recommends into an all-encompassing DoD future energy guiding coalition, designated as the OSD *Office of Assured Energy*, or USD(AE). This permanent office, in cooperation with force structure developers, would possess the overarching mission and authority to lead a comprehensive 40-plus year DoD energy transformation strategy toward the vision of a petroleum-free combat force that is relevant to 2050 and beyond. With the full support of the Secretary, the President, and Congress, this new office would be the driving force for DoD cultural and physical change vertically down to the lowest level of the organization, while simultaneously ensuring that the DoD both provides and receives maximum horizontal interagency support to meet DoD objectives as part of a larger and more aggressive national energy independence agenda.

Expecting to create additional bureaucracy or another undersecretary position without institutional skepticism would be unrealistic. One of the loudest arguments would be that government energy leadership belongs in the hands of the \$24B-a-year⁸³ DoE whose mission is "to advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission, and to ensure the environmental cleanup of the national nuclear weapons complex."⁸⁴ The energy security and scientific research strategic goals within the DoE's 2003 Strategic Plan include:

Goal 4. ENERGY SECURITY: Improve energy security by developing technologies that foster a diverse supply of reliable, affordable, and environmentally sound energy by providing for reliable delivery of energy, guarding against energy emergencies, exploring advanced technologies that make a fundamental improvement in our mix of energy options, and improving energy efficiency.

Goal 5. WORLD-CLASS SCIENTIFIC RESEARCH CAPACITY: Provide world-class scientific research capacity needed to: ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class research facilities for the Nation's science enterprise.

Examination of these goals reveals that when it comes to energy, the DoE is an institution that focuses primarily on science and technology research and development (R&D). The department's affirmation that its principal tool for implementing policy is conducting high-risk, high-value energy R&D at 24 world-renowned national research laboratories and facilities that the private sector alone would not or could not develop in a market-driven economy confirms this observation.⁸⁵ For the DoD assured-energy strategists, it is important to realize that the DoE performs its mission for a broad national clientele, not just the DoD. In this context, DoE's natural focus and obligation is to

perform basic research with the broadest potential impact (further reinforced in the Energy Policy Act of 2005). It is then up to individuals, corporations, institutions, and governments to apply this newly acquired knowledge for the greatest national benefit in a free-market system. DoE makes this relationship very clear in its strategic plan:⁸⁶

It is the role of the federal government to promote competitive energy markets, not to choose the energy sources for the country, now or in the future. *The Department's aim is to assist the private sector where appropriate to develop technologies capable of providing a diverse supply of reliable, affordable energy, and environmentally sound energy, while protecting the environment* (emphasis added). Market forces, *influenced by these Federal investments and other policies such as tax incentives and environmental regulation* (emphasis added), will determine the supply mix that consumers choose.

The tremendous lead times needed to uniquely adjust military force structure, systems, and doctrine may prevent the DoD from waiting for market forces to shape an energy future. This obligates the DoD energy strategists to be keenly aware not only of the DoE's ongoing efforts, but also of expected energy advances so that institutional changes can be made early enough to guarantee required combat capabilities are protected before petroleum scarcity becomes an issue. Understanding this situation is key to understanding why the DoD must actively lead its own energy transformation. DoE can and will accelerate transformation technology development as rapidly as the President, Congress, and DoD resource, but in the end it will still be up to the DoD to acquire, deploy, and absorb the risk of not having the technologies necessary to complete an energy transformation before petroleum supplies become a critical concern. Considering this relationship between DoD and DoE, it can then be argued that establishing an Undersecretary of Defense for Assured Energy office would not only provide the appropriate organizational level to synergize transformation activities within the DoD, but would also be perfectly suited to facilitate the necessary interagency cooperation with DoE's Undersecretary of Science office, as created by the Energy Policy Act of 2005, to accelerate energy technology development.⁸⁷

Assembling the right people is only the first part of creating a guiding coalition. The next two steps are to create trust and develop a common goal. Creating trust in a newly formed organization can be accomplished by dedicating the first several months, and up to the first year of the coalition's existence, to collectively gather information about DoD's multiple threats, required capabilities, energy vulnerabilities, and future concepts, while also gaining familiarity with international energy systems, alternate energy options, and anticipated problems to ensure that maximum knowledge is possessed prior to developing a post-petroleum vision and strategy. The daily immersion and interaction between members during this period can also be used to gradually reinforce the common goal of developing and executing the best energy strategy to ensure the US military remains effective and relevant to 2050 and beyond.

Create an Assured Energy Vision

Once formed into an effective guiding coalition, the Office of Assured Energy's first deliverable is to write the vision of an alternate energy future. The vision should refer to a picture of the future with commentary on why people should strive to create

that future.⁸⁸ Good vision is imaginable, desirable, feasible, focused, flexible, and communicable, and serves three important purposes.

- By clarifying the general direction for change, it simplifies hundreds or thousands of more detailed decisions.
- It motivates people to take action in the right direction, even if the initial steps are personally painful.
- It helps coordinate the actions of different people, even thousands and thousands of individuals, in a remarkably fast and efficient way.⁸⁹

By progressively moving backward in time from an effective vision of the future to the present day, the guiding coalition can then identify the milestones, tasks, and resources—the strategy—that will be necessary to create a petroleum-free military.

To frame the creation of an effective vision, the guiding coalition must possess a deep understanding of the threat it is trying to mitigate (loss of military effectiveness following Hubbert's Peak), the task for which the vision is being created (operationally executing America's NSS and NDS), and the options and resources (the means) that are reasonably available to construct the desired end state. The Office of Assured Energy's trust-building first year is designed to gather that knowledge. With recent advances in materials, biotechnical, and computational sciences, the technological solution set is building rapidly. Understanding the true pros and cons of each option may require significant objective learning on the part of each coalition member.

Today, the list of proven and most promising energy and technology options includes coal, natural gas, synthetic fuels, biofuels, nuclear power, hydroelectric power, wind power, solar power, oceanic power, hydrogen science, methane hydrates, material science and nanotechnology, fuel cell science, six-sigma concepts, and even enhanced use of petroleum. The scope of this article does not permit detailed descriptions of the identified emerging energy options. Only after understanding these energy sources and technologies, as well as the nation's defense and energy objectives, strategies, capabilities, and limitations, will the members of the Office of Assured Energy be ready to create an assured energy vision.

The visioning process can be lengthy and produce any number of possible outcomes, but for illustrative purposes, consider the following hypothetical proposal that is not only imaginable, desirable, feasible, focused, flexible, and communicable, but also aligns with the President's statements regarding a long-term national energy vision he sees for the United States:

The Vision – DoD Petroleum Independence by 2050

In 2050 the Department of Defense is a highly effective, networked, interdependent, and dominant military force, protecting all required American and allied interests, powered almost exclusively by an electrical and hydrogen energy standard that is reliably, efficiently, securely, and environmentally produced in a distributed manner without the need for foreign sources of energy.

The above vision statement represents the potential for a tremendous paradigm shift in the way modern forces wage war. Food, fuel, and ammunition logistics constraints have vexed commanders as long as war has existed. Envision the logistically

unconstrained maneuver capabilities of a force that is purposely designed to be 50 percent more efficient than today's force and requires no physical ammunition resupply and only a fraction of the liquid fuels consumed by today's forces. A directed-energy-based, highly automated force, capable of generating a majority of its own power in a distributed fashion from local and environmental sources, could theoretically provide that future. The potential efficiency, environmental ubiquity, universality and convertibility from one form to another of this configuration, make strong arguments that the force of 2050 can be powered almost exclusively by electricity and hydrogen.

Setting aside conventional paradigms allows one to imagine a conceptual 2050 force. All Navy ships might employ nuclear-powered, direct-electric drives, lightweight nano-engineered hulls, and directed-energy armament. All Army and Marine Corps future combat system land vehicles (many of which are unmanned) are designed for modular upgrades with plug-in electric hybrid or fuel-cell power, lightweight carbon nanotube-based armor, and directed energy weaponry. Today's vulnerable tanker fuel trucks are replaced with smaller hybrid or fuel-cell powered trucks carrying stable, solid hydrate-based hydrogen batteries or combat safety-engineered liquid hydrogen containers. Individual soldiers are outfitted with pocket hydrogen fuel cells to power 10 to 15 onboard electric systems. Virtually all combat fighter aircraft are small, unmanned or single-seat, and powered by liquid or even nano-engineered, solid hydrogen-based fuels. Ultra-efficient aircraft designs eliminate the need for tanker aircraft. All imagery, surveillance, and reconnaissance (ISR) platforms are either space-based or unmanned vehicles, orbiting for weeks at a time exclusively on solar-generated power while peering through weather from above. Similar platforms, orbiting alongside ISR brethren, reflect friendly, ground-based, directed-energy fires on rapidly moving enemy forces or weapons. Expeditionary bases would generate most base-support power autonomously through a flexible menu of options best suited for the particular mission or environment. Choices could include truck-portable nuclear electric generation (for secure environments); waste-stream and local biomass biofuel production; portable wind generation; extensive solar energy systems; ocean thermal; solar photolysis or hydrocarbon-based hydrogen production; high-efficiency, thermoelectric waste-heat recovery; fuel cells; or quite simply, local electrical grid connection—whatever best suits the situation.

Every networked physical component within the 2050 force structure would possess low-power optical computing; very low-power LED lighting; nano-engineered, superconducting power transmission; whole-surface, thin-film solar panels; a modular construct to enable component upgradeability, and most importantly, all systems would use the same universal electrical standards to ensure interconnectivity. Most systems could recharge from an expeditionary base local power grid during nonactivity periods, but would also be capable of enhancing unit survivability and flexibility by using excess onboard power production to energize the unit grid or any other single force component if its primary means were rendered ineffective. Operational-level energy could be delivered from sea-based, nuclear powered, hydrogen production ships. Strategic energy augmentation from orbiting solar-generation satellites or space-based relay satellites linked to terrestrial continental United

States generators could even be delivered via microwave to a suitably configured tactical receiver anywhere in the hemisphere.

While the envisioned force of 2050 may sound as if it is a Star Wars fantasy to some, imagine how the following vision statement may have sounded to the War Department in 1906:

In 1950 the US military is a highly effective, mobile, and mutually supporting force, protecting all required American interests through dominant air, land, and sea operations powered by a petroleum energy standard that is reliably and economically produced from domestic sources.

Most of the horse-riding officers at the time would likely not have even imagined the aircraft carrier-, jet fighter-, and tank-based force America went to war with against North Korea 45 years later. The vision of a petroleum-independent military in 2050 is certainly imaginable, and virtually each of the systems concepts discussed has already been proven physically feasible, or at least theoretically so. Proposing a hydrogen-electric standard focuses all subsequent development activity into the framework of a purpose-designed force, while sufficient flexibility remains in the vision so as to not force specific solutions. Finally, the vision communicates a desirable future in which military effectiveness is preserved, but where security, efficiency, environmental consciousness, and energy independence are also achieved. It is clear that by eliminating the constraints of conventional paradigms in any problem-solving exercise, a potentially better, revolutionary future can be envisioned. Converting what exists today into the future of tomorrow is the realm of strategy. The following section examines how to develop the best strategy to create the vision of a petroleum-free Department of Defense.

Developing an Assured Energy Strategy

The magnitude of the DoD's fuel consumption indicates substantial changes must be made in the performance DoD requires of its future systems in order to achieve the goals of JV2010 and JV2020.

—Defense Science Board Task Force on Improving Fuel Efficiency in Weapons Platforms, OSD (AT&L), January 2001⁹⁰

Building Strategy from a Vision

Forty-five years ago, on 25 May 1961, under the very real security threat of losing a space race with the Soviet Union, President Kennedy issued to the nation an urgent challenge of placing a man on the moon by the end of the decade.⁹¹ Given the state of rocket technology in 1961, President Kennedy knew that, to many, the goal of landing on the Moon 230,000 miles above the Earth seemed impossible. With great foresight he stated:⁹²

I believe we possess all the resources and talents necessary. But the simple facts of the matter are that we have never made the national decisions or marshaled the national resources required for such [international] leadership. We have never specified long-range goals on an urgent time schedule, or managed our resources and our time so as to ensure their fulfillment.

Let me make it clear that I am asking the Congress and the country to accept a firm commitment to a new course of action, a course which will last many years and carry very heavy costs.... This

decision demands a major national commitment to scientific and technical manpower, material and facilities, and the possibility of their diversion from other important activities where they are already thinly spread. It means a degree of dedication, organization, and discipline, which have not always characterized our research and development efforts.

What President Kennedy gave America was a vision, a vision of *a future it could create*, a vision each American could personally imagine by simply gazing upward on any cloudless night. Working *backward* from the President's clearly stated goal, thousands of Americans from government, industry, and academia teamed together to correctly dissect one seemingly *insurmountable* problem into thousands of smaller solvable ones. Only 8 years later, through courageous leadership, teamwork, and pure determination, a Saturn V rocket lifted the Apollo 11 astronauts to the moon. While the energy-Apollo problem scope cited here is not an original analogy, the similarities in trying to solve a grand challenge are compelling and can serve as an example of how the DoD can focus government, science, and industry to ensure the US military has the energy to guarantee America's security to 2050 and beyond.

The methodology for forming a strategy requires starting at the desired end state and stepping backward in time toward the present to identify the hierarchy of goals that must be met to support follow-on achievements. For example, in order to deploy an envisioned hydrogen-powered force, the capability to effectively and efficiently produce hydrogen fuel must first exist. Before the capability to produce hydrogen fuel exists, certain technical challenges must be solved, and before that, certain research institutions must be formed and resourced. This deductive process can be repeated hundreds of times over to design a complex system or system of systems. In this manner, a series of milestones is identified to serve as short-term wins that Kotter states are essential for sustaining the transformation process.⁹³

In the case of creating a future hydrogen- and electric-powered force, there are two primary strategies.

- Allow market forces and timing to create and deliver necessary transformational capabilities (the DoE model).
- Allow the DoD to lead an energy transformation much as it did the race into space (with NASA), the adoption of computational problem solving, or creating ubiquitous modern high-speed commercial air travel through development of the high-bypass turbofan jet engine.

The fundamental difference between the two is acknowledging who must bear the risk of stranded development in an environment with an as-of-yet unclear future—should it be the commercial sector or government to bear that responsibility? As previously argued in the second section, the unique acquisition lead times and vital responsibilities of the DoD may force it to address this problem long before market forces have identified winning solutions. This fact is therefore the basis for selecting the latter option for examination in this article. A strategy of waiting for market forces to deliver options is not without merit.

Working backwards from the vision, the overarching strategy can be imagined to address the following tasks:

- Acquire alternate-fueled systems
- Create an alternate fuel delivery infrastructure
- Develop new energy standards
- Determine a new energy force structure
- Conduct R&D to acquire transformational technologies
- Throughout the process, protect against negative oil peaking effects to allow sufficient transformation time
- Minimize transformation costs
- Preserve military capability during the transition

This type of temporal task ordering is not new but demonstrates that a logical flow exists from the present condition to the desired end state, which in this case is complicated by the need to preserve defense capability while transitioning away from significant legacy investments in a resource-constrained environment. The strategy for accomplishing these tasks will take several decades and can be subdivided into three separate phases: 2006-2020, Near Term; 2020-2035 Mid-Term; and 2035-2050, Long Term.

A Three-Stage Approach

The DoD would be best served to lead three stages to military petroleum independence:

- A near-term (2006-2020), DoD-wide focus on establishing proper strategic leadership, energy efficiency, conservation, acquisition reform, bridge energy sources, and research and development (R&D)
- A mid-term (2020-2035) focus on infrastructure and technology transition
- A far-term (2035-2050) focus on employing the new energy

Quite simply, the concept is to use the DoD's enabling hierarchy and economic leverage of a \$400-plus billion annual budget to reduce or reverse the annual rise in energy consumption while simultaneously developing bridge energies that will buy the necessary time for an intensive DoD and DoE-facilitated R&D effort designed to discover and deploy distributed, clean, diverse, affordable, and self-sustaining energy sources before petroleum scarcity or high prices impact military capability even more severely. Using a process that Amory Lovins calls *creative destruction*,⁹⁴ the new energy conversion must occur in a way that maximizes the remaining return-on-investment value of legacy systems while simultaneously enabling a convincing paradigm shift for users toward the new energy. Much as DoD-funded projects like Arpanet and the global positioning system set early industry standards that gave the commercial sector the framework upon which to create exponential market developments, so too could the early establishment of new energy infrastructure standards (production, transmission, connectivity, and modularity) prove to be the DoD's greatest contribution to America's long-term energy security.

Stage I – 2006-2020 Near-Term Strategy

Five up-front activities can be initiated through effective and immediate DoD policy changes.

- Establish the Office of Assured Energy
- Increase energy efficiency and conservation

- Promote acquisition reform
- Develop bridging energy sources to buy time
- Complete intensive R&D efforts for the new energy beyond petroleum

Establishing the Office of Assured Energy

After creating a DoD energy vision, the Office of Assured Energy's next most important task would be to accomplish Kotter's fourth step in leading change, which is communicating the change vision to create a common understanding of its goals and direction.⁹⁵ To prepare the entire DoD, industry, and academia for the magnitude of change they are about to help create, the Office of Assured Energy must effectively convey the urgency of the energy problem facing the DoD, the envisioned petroleum-free future, the fundamental transformations that will need to unfold over the course of several decades, the breadth of the leadership role the Office of Assured Energy will directly play in that transformation, and the commitment that will be required of leadership and each individual member of the organization in helping create a more secure envisioned energy future. The message should be simple, continuous, and ubiquitous, and those delivering it should be prepared for both positive and negative feedback as they work to overcome the resistive forces of doctrinal dogma and risk aversion.⁹⁶

Increasing Efficiency and Conservation

The first logical physical step toward any long-term petroleum independence is reducing consumption through increased efficiency and conservation. The military has always valued capabilities and effectiveness (such as speed, mass, stealth, and so forth) over efficiency for good reason—restraint when national survival is at risk is illogical. However, this is a short-term perspective and in an energy-constrained environment, efficiency becomes its own effect, enabling the sustained application of other desired military effects. Not only does conservation through increased efficiency directly and immediately enhance and help stabilize an organization's typically tight budget from gross energy cost fluctuations (such as after Hurricane Katrina, Operation Desert Storm, or Operation Iraqi Freedom), it also lays the necessary groundwork for enabling new alternate energy futures. If, for example, some new promising energy technology still requires a 20 percent process efficiency increase in the system it would support in order to become feasible, then the argument for making the original system 20 percent more efficient is powerful not only because it saves petroleum energy costs in the short term, but it also pushes the realm of the new technology from the theoretical to the practical, and should therefore be pursued whenever possible to preserve needed military capabilities.

To date, the definitive DoD internal document advocating increased efficiency remains the 2001 Defense Science Board (DSB) Task Force on Improving Fuel Efficiency of Weapons Platforms' report entitled, *More Capable Warfighting Through Reduced Fuel Burden*. It identified five major efficiency recommendations.

- Base investment decisions on the true cost of delivered fuel, warfighting, and environmental benefits
- Strengthen warfighting and fuel logistics links in wargame modeling

- Have leadership incentivize fuel efficiency throughout the DoD
- Specifically target fuel efficiency improvements through investments in science and technology and systems designs
- Explicitly include fuel efficiency in requirements and acquisition processes

Arguably, it is the report's third suggestion, "Have leadership incentivize fuel efficiency throughout the DoD," that is the most important and transformational.⁹⁷ The authors go on to emphasize:

For the DoD to take advantage of the large cost and performance benefits of significant improvements in weapons platform fuel efficiency, senior civilian and military leadership must set the tone and agenda within the Department. Leadership must begin promoting the message that efficiency at the tactical platform and system level is a clear strategic path to improve performance, reduce logistics burden and free resources for modernization and readiness. This needed emphasis by DoD leadership is not merely desirable; it is an essential ingredient to achieve the force improvements to execute Joint doctrine.⁹⁸

While looking specifically at improving existing and future weapon systems, the DSB's advice applies equally well to all operating procedures and installation infrastructure as well. This is a message that all Service chiefs and combatant commanders could broadcast loudly and repeatedly through their established information outlets. Subordinate levels of command would have to internalize and demonstrate acceptance of these concepts to junior ranks until even basic recruit and contractor behavior reflects the DoD's emphasis on efficiency and conservation. Success will depend largely on providing meaningful behavior change incentives to energy users for the purpose of long-term payback. One incentive model could be to return any normalized energy savings over the previous year directly to the saving organization—a potentially powerful motivator for under-resourced units. It is important, though, that to avoid the temptation of compromising safety to earn energy efficiency rewards, commanders and leaders not be penalized for exceeding the previous year's normalized energy bill. Bottom line: properly incentivized people will make a difference.

Promoting Acquisition Reform

To date, DoD acquisition has undervalued weapons system efficiency as a critical desired system effect. In 2001 the DSB Task Force on Improving Fuel Efficiency of Weapons Platforms, remarked,

Efficiency attributes are not addressed in the acquisition process. Military requirements documents understandably place the highest priority on performance. Energy and fuel efficiency would become a major design variable if specified as key performance parameters (KPP).⁹⁹

The board continued,

The PPBS does not reward efficiency or penalize inefficiency. Interest in fuel and energy efficiency is largely limited to meeting federal executive orders or legislative mandates. However, since federal mandates do not apply to military weapons systems, there are neither policy focus nor resource incentives to seek operational fuel efficiencies. Consequences of no efficiency requirement and a subsidized fuel price are that investments to improve efficiency do not compete well (or at all) in the PPBS process—the result is increased costs and degraded warfighting capability.¹⁰⁰

There are several examples of the type of efficiency-related changes the DoD might consider as a matter of ongoing acquisition policy reform. First, as the DSB suggests, all future operational requirements documents could require an energy efficiency KPP for systems and infrastructure purchases. In one approach, acquisitions that would last 5 years or less, commercial-equivalent, state-of-the-art efficiency would be acceptable; for acquisitions lasting more than 5 years, the KPP should require an efficiency standard better than state of the art. If better-than-state-of-the-art is not immediately feasible, then the new system would have to adhere to the second proposed change, which is that it must start with state-of-the-art efficiency at the time of acquisition but possess modular upgradeability such that, as more efficient subsystems and components are developed, they can be interchanged with legacy components to reduce life-cycle energy costs and maximize legacy system total return (this is a critical concept—it answers the question of how to avoid discarding inefficient legacy systems and how to minimize the risk of stranded investments). A required element of the efficiency KPP would be to require each new system or facility proposal to calculate estimated operating energy costs based on the price of delivered energy at the point of use as the DSB suggests—this is similar to the familiar yellow *Energy Guide* labels found on major home appliances. The third change is to begin requiring proposed systems to adhere to the new energy standards (connectors, power and energy quality, operating limits, and so forth) as they are developed and approved by the Office of Assured Energy in conjunction with appropriate DoD partners like DoE or industry standards consortiums. Actual adoption of this third step into hardware design will be the signal of progress and will mark one of the DoD's most important contributions to the expansion of energy reform for American society at large.

Developing Bridge Energies

Conservation and efficiency can provide immediate returns, but the total impact will not be sufficient to eliminate foreign petroleum dependence. Because full-scale transition to the new energy will take at least 40 years to complete, and many professionals predict Hubbert's Peak will occur by 2020, bridge energy sources are necessary to maintain combat capability. Bridging energy sources are those energies and fuels other than petroleum which are available or can be made available in sufficient quantity in the near term to supply necessary energy needs until a revolutionary energy is deployed. Examples include natural gas; synthetic fuels from oil shale, tar sand, or coal liquefaction; nuclear power; possibly methane hydrates; and renewables like biofuels, solar, wind, and geothermal power.

Catalyzed by the 2002 Clean Fuels Initiative, the DoD began exploring the mechanics of liquid fuel production from Western US oil shale and Canadian tar sands through the German-developed Fischer-Tropsch process used in World War II.¹⁰¹ The Clean Fuels Initiative segregated development into two parallel foci:

- Total energy development for overcoming the economic and technical obstacles necessary to enable large-scale industrial fuel production
- Certifying a Joint battlespace use fuel for the future as a single nonpetroleum-derived fuel suitable for use in all current, legacy, and emerging systems.¹⁰²

In its Energy Policy Act of 2005, Congress formally authorized the DoD to pursue development of coal/shale/sands fuel extraction technologies with the statement,

The Secretary of Defense shall develop a strategy to use fuel produced, in whole or in part, from coal, oil shale, and tar sands (or other resources) that are extracted by either mining or in-situ methods and refined or otherwise processed in the US in order to assist in meeting the fuel requirements of the DoD *when the Secretary determines that it is of national interest.*¹⁰³

It appears that time has come through the advocacy of Mr. John Young, representing the Naval Research Advisory Committee (NRAC). His October 2005 post-Hurricane Katrina memo to USD (AT&L) (and subsequently endorsed by the Air Force), stated,¹⁰⁴

I believe that DoD can complete the necessary due diligence and have a program well underway within 3 years. With sufficient priority we can achieve initial operational capability by 2011 and full energy independence for DoD by 2020." He continues, "We can do this by making a long term commitment to shift from petroleum products to manufactured fuels produced by assured domestic sources of supply. Such a DoD commitment now could also generate economic benefits for the Department and the nation in 5-10 years. In light of the current painful reality of DoD fuel price adjustments, and the risks to our fuel sources posed by natural disasters and terrorists threats, I believe we need to act on this recommendation *with a sense of urgency* (emphasis added).¹⁰⁵

At the time of this writing, it appears that OSD is poised to commit toward leading development of synthetic fuels from oil shale, tar sands, and coal. The promise of 2 trillion barrels of oil equivalence, the need to supply the DoD with approximately 400,000 barrels of oil per day by 2020, the fact that Canada already produces 1 million barrels of oil per day using these techniques from Albertan tar sands (of which 95 percent is already sold to the US),¹⁰⁶ and the existence of Congressional preapproval makes this low-risk decision virtually inevitable. Many would claim this event marks the end of US petroleum worries; there is no need to be concerned about alternate energies if the DoD can catalyze industrial production by 2020—Hubbert's Peak becomes a nonevent. This program, however, may not provide a permanent panacea.

The primary benefit of using synthetic liquid fuels is that virtually no infrastructure modification is necessary—simply certify all current engines for use and start pumping shale oil into the existing fuel distribution system and America's air, sea, and land power is preserved. However, four problem areas arise from military reliance on synthetic fuels as a potential long-term energy solution:

- Increased lines-of-communication (LOC) demands
- Potential environmental harm (strip mining, high-water consumption, CO₂ emissions)
- Increased public-sector synthetic fuel consumption
- Neglected allies

According to Defense Energy Supply Center standard procedures, the DoD globally purchases fuel from regional and local suppliers at a DoD-wide contract price. Oil corporations ensure that adequate regional supplies exist through an established global shipping and distribution system, while organic military systems provide final fuel delivery into combat

zones or to end users. The DoD's universal adoption of oil-shale fuels by 2020 will create a unique distribution situation not seen since the US last exported fuel: the flow of full tankers *leaving* US seaports! It is unclear from available literature what type of cargo these ships will carry—will it be finished fuels or unrefined crude requiring dependence on potentially vulnerable host nation refining before it is ready for use? Project sponsors must specify this information in their proposals. Additionally, is the US Navy prepared to protect these shipments that an asymmetric enemy could clearly identify and target on the open seas? Because it would flow through the existing petroleum distribution infrastructure, the post-2020 synthetic-fuel military might end up relying on a reversed supply system as fragile and vulnerable as today's.

Virtually every industrial process comes at an environmental cost—coal/shale/tar sand oil is no exception. While it is widely known that the Fischer-Tropsch (FT) process produces liquid fuels that burn cleaner than their petroleum-derived counterparts, the environmental advantage ends there. Oil shale/tar sand/coal extraction requires intensive mining operations—subterranean and strip processes in the Appalachians and strip mining in Wyoming and Colorado, where the largest deposits are found. Strip mining would tear open vast tracks of pristine wilderness and destroy natural habitats. The alternative is to liquefy underground solids with electrical heaters—a process that requires substantial energy of its own. Combine that with the one to four barrels of water and 400–1,000 cubic feet of natural gas needed to refine each barrel of shale oil¹⁰⁷ in a historically water-scarce region of the country, and the millions who live downstream of the Colorado River will certainly raise loud voices. Finally, shale oil products release a significant amount of CO₂, the primary cause cited in the theory for global warming. The significant amounts released during the FT extraction process can be sequestered below ground, but wide scale adoption of synthetic fuel does not prevent release of CO₂ at the point of end use combustion. Consuming approximately 400,000 of the world's estimated 120 million barrels a day by 2020,¹⁰⁸ one could successfully argue that the DoD's contribution to global environmental harm would be relatively negligible, but taking a minimalist approach would not excuse the program from addressing the third looming issue with the DoD conversion to shale-oil: purchasing competition from a growing public sector demand for synthetic fuel.

Preliminary studies have shown that coal/shale/sands oil production becomes economically feasible at approximately \$45 a barrel.¹⁰⁹ Considering oil's recent \$70-a-barrel peak, and the fact that each \$1 per barrel price increase costs the DoD \$135M annually,¹¹⁰ synthetic fuels become very attractive financially. It would only be realistic to assume that the same attraction drawing the DoD to shale-oil conversion would also generate a surge of public-sector consumption for the fields of Wyoming. On one hand, increased economies of scale should help drive down production costs for the DoD, but since oil is a commodity, one must expect synthetic oil to sell for the same volatile price as petroleum oil. Philip Deutch, in his 2005 *Foreign Policy* article "Energy Independence," correctly observes that, "No private oil company will sell oil on its domestic market for one penny less than it could realize on foreign markets, and the price that a barrel of oil commands will be based upon pressures beyond any one government's control."¹¹¹

Unless the US government enters long-term contracts or cooperatives with producers to provide federal fuel at a fixed price in exchange for Department of the Interior mining rights on federal lands, free-market forces will negate the last portion of the NRAC's justification for oil-shale development: "Setting a 2020 goal of complete conversion to assured domestic sources of manufactured fuels will enhance national security and potentially save money compared to riding the curve of rising global petroleum prices."¹¹²

The final concern with the DoD reliance on shale-oil regards America's strategic allies and friends. Today, and to 2020, allies such as Canada and the United Kingdom can approximately meet or exceed domestic and security needs. However, nations such as Germany, France, or Japan already rely upon imported oil for over 90 percent of their requirements. None of these allies have sufficiently vast solid hydrocarbon reserves to accomplish their own internal shale, coal, or tar sands conversion. For these countries, military foreign energy independence will be a virtual impossibility by 2020, severely shaping the foreign policy objectives and freedom of these nations reliant on petroleum imports. Unless the United States is willing to develop its synthetic fuels resources beyond the levels needed to power only the DoD, many of America's international military partners may simply be unavailable for the coalitions the US has acknowledged it will need to favorably shape tomorrow's world.

Synthetic liquid fuels are only one bridging energy alternative. At present, they provide the only real option for mobile systems which rely on high-energy-density liquid hydrocarbon fuels to provide the maneuver and logistics capability that allows the US military to dominate all others. They would be intended to serve as the main mobility bridge to the 20-40 year hydrogen energy future America has placed great faith in, as evidenced by the 2005 Energy Policy Act allocating \$2.1B for hydrogen research over the next 5 years.¹¹³ In the meantime, other bridging options exist for nonmobility energy requirements such as base facilities at home, overseas, and in expedition. If fully developed, many of these emerging installation bridge energies can become permanent infrastructure energy solutions.

There is positive news to report in the area of installation bridge energy development. Here the DoD is accomplishing true energy leadership by leading the federal government in the purchase of Green Energy. This effort was in response to a 2 November 2004, DoD-wide memorandum from the Honorable Phillip W. Grone regarding installation energy policy goals. Mr. Grone stated that,

The DoD will strive to modernize infrastructure, increase utility and energy conservation and demand reduction, and improve energy flexibility, thereby saving taxpayer dollars and reducing emissions that contribute to air pollution and global climate change.¹¹⁴

In addition to directing a reduction of installation petroleum use, Mr. Grone also directed that,

Each Defense component shall strive to expand the use of renewable energy within its facilities and in its activities by implementing renewable energy projects and by purchasing electricity from renewable energy sources.¹¹⁵

The Air Force began adopting this practice long before 2004, resulting in the Environmental Protection Agency announcing that the Air Force was the largest single buyer of renewable energy, responsible for 40 percent of all purchased by the federal government in 2004.¹¹⁶ Edwards AFB was able to meet 60 percent

of its annual energy needs by securing a 5-year contract that saved \$42M over fluctuating conventional electrical prices. Fairchild AFB is nearly 100 percent Green Energy from supporting local wind farms. Dyess AFB became the 2003 Green Power Partner of the Year as the nation's largest, single-point Green Energy consumer, meeting 100 percent of its electrical needs.¹¹⁷

Other Services are following suit, which allowed OSD to provide a positive report to Congress on 14 Mar 2005 that, "...at the end of 2004, 2.5 percent of energy used by US military installations came from renewable sources."¹¹⁸ In addition, the report stated that, "While the current level of the DoD's renewable energy use meets the federal goal set by DoE, it only represents a small fraction of the possibilities."¹¹⁹ The Air Force has already demonstrated the ability to operate one base on 100 percent renewable power. Therefore, if all installations adopted some form of this goal, commercial renewable energy suppliers would be incentivized to develop more capacity. In fact, demand for wind power has been rising so rapidly that 2005 was a record year for the US, with 2,500 mega watts of new capacity installed, resulting in a 35 percent increase in national production capacity and the US being at the top of all countries for new installations.¹²⁰

The wind power explosion is not a solo actor in the race to develop bridging energies. Solar power has seen dramatic price drops in recent years with the emergence of exciting new technologies such as solar-electric shingles, thin-film solar, and solar day lighting offering opportunities for bases to pay a onetime energy installation cost and then reap free energy for the life of the system. Many of the technologies can also be used in expeditionary environments. These types of exciting advances have led OSD to make such commitments to Congress as, "Where economical, DoD should pursue on-installation production of renewable energy because it provides energy savings, reduces our dependence on foreign energy, and saves money, while increasing energy security."¹²¹ OSD further states,

DoD is continuing its historic role as a catalyst for the development of other emerging renewable technologies. The DoD's renewable energy vision is to maintain a commitment to renewable energy supported by a DoD-wide appreciation for the economic, environmental, and security benefits of renewable energy technologies.¹²²

Quite simply, the DoD's installation renewable energy program demonstrates the positive effects of a coherent DoD energy strategy fully supported by leadership. This warm-up event can provide valuable lessons and the short-term gains Kotter claims are mandatory to sustain motivation¹²³ for the much larger and anticipated upcoming fuels transformation event.

Energy Research and Development

The final required element in the DoD's quest for foreign oil independence is the re-creation of R&D accomplishments on the scale that allowed America's aerospace engineers to send Neil Armstrong to the moon. After decades of successful innovation since Apollo, President Bush and others have stated that today America's global innovation leadership position is under attack by the effects of globalization. On the positive side, US companies can significantly reduce costs by outsourcing both menial and intellectual work for pennies on the dollar in a globalized world. On the negative side, the growing lack of interest (and ability) on the part of American students to pursue engineering and

science degrees, coupled with a reverse brain-drain of R&D talent back to new renaissance countries like India and China, has left the US with a quickly aging science and engineering community and the prospect of losing its position of science and technology leadership in the world. To illustrate, last year in Germany 36 percent of undergraduate students earned degrees in math and science, in China 59 percent, and in Japan 66 percent—in the US the figure was only 32 percent.¹²⁴ In 2004, China graduated over 600,000 engineers, India 350,000, and America only about 70,000.¹²⁵ Underscoring the President's acknowledgment of this problem in his 2006 State of the Union Address,¹²⁶ the National Academy of Sciences (NAS) Committee on Prospering in the Global Economy of the 21st Century best articulates the alarm in their 2005 report, *Rising Above the Gathering Storm*, in which they state,

It is easy to be complacent about the US competitiveness and preeminence in science and technology. We have led the world for decades, and we continue to do so in many research fields today. But the world is changing rapidly, and our advantages are no longer unique. Without a renewed effort to bolster the foundations of our competitiveness, we can expect to lose our privileged position. For the first time in generations, the nation's children could face poorer prospects than their parents and grandparents did....The US faces enormous challenges because of the disadvantage it faces in labor costs. Science and technology provides the opportunity to overcome this disadvantage by creating scientists and engineers with the ability to create entirely new industries (emphasis added)—much as has been done in the past.¹²⁷

In response to their alarm, the committee identified two challenges tightly coupled to scientific and engineering prowess: creating high-quality jobs for Americans and responding to the nation's need for clean, affordable, and reliable energy.¹²⁸ The NAS identifies a nexus of opportunity that simultaneously strengthens the economy and national security while simultaneously solving America's looming energy crisis—the intense application of an R&D commitment that promises intellectual and financial reward for those Americans already inspired, and those yet to be inspired in the sciences. With a DoD commitment to lead its own energy revolution, the US could create an entirely new, leading-edge commercial sector for the global market; a sector that could propel the US economy for decades and turn this nation into a new energy or energy technology exporter, much like the US achieved in the 1940s and 1950s when it dominated the export of petroleum development technology.

Solving future energy problems for the DoD and the US will take 20 to 40 years—an inspiring and exciting potential lifetime career for a new engineering graduate. Could the DoD possibly partner with the Department of Energy to create a world-renowned New Energy Research Center of Excellence? To generate the necessary intellectual enthusiasm and capability for this endeavor, the NAS proposes four recommendations listed below (including some selected subpoints), with implementation responsibility falling to Congress; the Departments of Energy, Education, and Defense; and the National Science Foundation:¹²⁹

- **Recommendation A:** Increase America's talent pool by vastly improving K-12 science and math education.
- **Recommendation B:** Sustain and strengthen the nation's traditional commitment to long-term basic research that has

the potential to be transformational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.

- Increase the federal investment in long-term basic research by 10 percent a year over the next 7 years. Special attention should go to the physical sciences, engineering, mathematics, and information sciences, and to DoD basic research funding.
- Allocate at least 8 percent of the budgets of federal research agencies to discretionary funding
- Create in DoE an organization like the DARPA called the Advanced Research Projects Agency-Energy (ARPA-E). The agency would be charged with sponsoring specific research and development programs to meet the nation's long-term energy challenges. ARPA-E would be based on the successful DARPA model and be designed as a lean and agile organization with a great deal of programs that can start and stop programs based on performance. The agency would perform no research or transitional effort but would fund such work conducted by universities, start-ups, established firms, and others.
- **Recommendation C:** Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world.
 - Increase the number and proportion of US citizens who earn physical sciences, life sciences, engineering, and mathematics bachelor's degrees by providing 25,000 new 4-year competitive undergraduate scholarships each year to US citizens attending US institutions.
 - Increase the number of US citizens pursuing graduate study in *areas of national need* by funding 5,000 new graduate fellowships each year.
- **Recommendation D:** Ensure the US is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs that are based on innovation by modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.

The aviation and computer industries exploded shortly after they were created because hundreds of thousands of innovators were interested in the fascinating subject matter and expended tremendous personal energy expanding these fields. The potentially dark future of conventional energy supply is sufficient to generate the same type of broad interest that aircraft and computers still enjoy today. Scientists and engineers live for the excitement of new discovery and associated peer recognition—it may be as simple as DoD and DoE creating the R&D opportunities so that the inspired will come. Case in point is DARPA's recent Grand Challenge contest. By offering a \$2M prize to the university, industry, or government team that could build an autonomous vehicle capable of auto-navigating 131 miles of Mohave Desert, DARPA received some 20-plus approaches to solving the problem with a clear demonstration of what works and what does not.¹³⁰ Much as the Gossamer Albatross and Spaceship One were inspired by standing prizes, the DoD may find its energy answers in a team of bright college students competing to win a million dollars of government prize

money. Could innovation prizes be the DoD's low-budget R&D model of the future? It certainly appears to be one attractive low-cost option for the government.

Where can the DoD best focus R&D efforts to maximize energy solutions? Fortunately, work has begun in all necessary fields, but the energy research percentage in the Department's \$75B FY05 R&D budget would likely still need to be increased substantially to help create the new energy before Hubbert's Peak arrives.¹³¹ The President has proposed a 22 percent increase in certain areas of federal government alternate energy research even though the Energy Policy Act of 2005 already allocates \$7.5B of R&D funds over the next 5 years.¹³² Four areas of possible focus spring to the forefront.

- Efficiency technologies
- Nanoscience
- Energy and power technology initiatives
- Infrastructure technologies

The 2001 Defense Science Board Task Force for Improving Fuel Efficiency of Weapons Systems recommended that the DoD,

Specifically target fuel-efficiency improvements through investments in science, technology, and systems designs. DoD labs could produce a large number of technologies in their portfolios that could improve the efficiency of their platforms and systems; a consistent message was that their customers, the operators, were generally not asking for efficiency. The science and technology community should make platform efficiency a primary focus to identify, track, and package technologies that improve efficiencies. It is fundamental that the DoD support (Category 6.1 and 6.2) investments that can lead to revolutionary improvements in the fuel efficiency of tomorrow's weapons platforms.¹³³

For instance, with thousands of gas turbine engines in the inventory consuming billions of gallons of fuel annually, every percentage increase matters—programs such as the Versatile Advanced Affordable Turbine Engine are critical. Agencies such as the Air Force Research Laboratory already seek engine efficiency gains as elements of contracted research projects but need dedicated funds for the sole purpose of revolutionizing aircraft propulsion. A good example of such a project was the development of the hydrogen-fueled PW304 jet engine designed and tested in the 1940s and 1950s for the *Suntan* project.¹³⁴

The exciting and new field of nanoscience offers great hope for a DoD energy vision. As part of the National Nanotechnology Initiative, the National Science and Technology Council's Nanoscale Science, Engineering, and Technology Subcommittee concluded that,

At the root of the opportunities provided by nanoscience to enhance our energy security is the fact that all of the elementary steps of energy conversion (charge transfer, molecular rearrangement, chemical reactions, and so forth) take place on the nanoscale.¹³⁵

DoE's Basic Energy Sciences Advisory Committee's "Basic Research Needs to Assure a Secure Energy Future" and their Office of Basic Energy Science's "Basic Research Needs for the Hydrogen Economy" have recognized that solutions will require scientific breakthroughs and truly revolutionary developments. Within this context, nanoscience and nanotechnology present exciting and requisite approaches to addressing these challenges.¹³⁶ Participants of the March 2004 National

Nanotechnology Grand Challenge Workshop identified nine research targets in energy-related science and technology in which nanoscience is expected to have the greatest impact.¹³⁷

- Scalable methods to split water with sunlight for hydrogen production
- Highly selective catalysts for clean and energy-efficient manufacturing
- Harvesting solar energy with 20 percent power efficiency and 100 times lower cost
- Solid state lighting at 50 percent of the present power consumption
- Superstrong and lightweight materials to improve the efficiency of cars, planes and the like
- Reversible hydrogen storage materials operating at ambient temperatures
- Power transmission lines capable of 1 gigawatt transmission
- Low-cost fuel cells, batteries, thermoelectrics, and ultra-capacitors built from nano-structured materials
- Materials synthesis and energy harvesting based on the efficient and selective mechanisms of biology

Involving the basic building blocks of all matter, the nine material science areas above indicate that the foundation of the world's energy future lies within nanoscience research.

The third area of impact involves enhancing the DoD's 2001 Energy and Power Technologies Initiative (EPTI). Expanding across all military Services in only 5 years, EPTI's objective is to revolutionize the energy and power components of military systems to enable an envisioned *all-electric* force. Divided into power generation, energy storage, and power control and distribution categories, EPTI will draw heavily from nanoscience discoveries and quantum physics to create the physical components (electric motors, batteries, capacitors, low-resistance wiring, electric actuators, and high-power electronics) necessary to reduce the logistics burdens and operational capabilities of future military systems.¹³⁸ Each new advance should cascade rapidly to other DoD systems, which in turn will inspire other new applications discoveries. Most importantly, EPTI technologies have the potential to gain rapid public sector use propelling mass-production cost reductions and even greater innovations. Already funded at over \$250M for research this year,¹³⁹ this funding level could easily again be tripled or quadrupled to accelerate innovation returns with the strategic blessing of a hypothetical *Office of Assured Energy*.

Although energy infrastructure is perhaps the least glamorous of all the research areas, it is as fundamental to the total solution as discovering the *Holy Grail Fuel of the Future* itself. In lockstep with the most promising of any new fuels or energy research must be the development of the systems that will produce and distribute the new energy. By objectively examining the most promising alternatives early, the DoD can be the first to establish new industry standards for energy quality, format, interconnectability, transportability, and so forth, to maximize universality and modularity. The consumer electronics industry demonstrates time and again how a particular technology will not flourish until an industry standard is established (for example, Betamax versus VHS, CD, and DVD formats). The computer industry did not expand rapidly until adoption of universality

and modularity allowed users to custom configure and continually upgrade their systems, preserving their legacy investments. This model can be seized upon and articulated early by the DoD—until this is accomplished, neither military nor commercial developers have frameworks to build upon. Creating these frameworks through future acquisition requirements would serve as a catalyst for industrial activity and could become the DoD's greatest contribution to energy security.

Stage II – 2020-2035 Mid-Term Strategy

If the seeds of change are to be sown in Stage I of an energy transformation strategy, then the concept and idea seedlings must be cultivated in Stage II before the benefits can be harvested in Stage III. By the end of Stage I, the DoD should have internalized the commitment of energy transformation across the entire department, selected its primary and supporting long-term future energy sources, deployed necessary bridging energies, and created the necessary R&D momentum and energy standards to support the transition to Stage II. In Stage II the DoD would need to focus on:

- Adjusting force structure for the new energy future
- Adjusting operational training and procedures
- Investing in new energy infrastructure and transition technologies while continuing intense R&D efforts to meet the Stage III goal of remaining militarily relevant in 2050 and beyond

Adjusting Force Structure

The world's looming energy situation has the potential to dictate historic force structure decisions. The DoD's primary mechanism to assess force composition relative to threats and *Joint Vision 2025* goals is the *Quadrennial Defense Review* (QDR). This comprehensive approach produces force structure decisions that the Services are subsequently expected to execute. In the February 2006 QDR, no force structure decisions were made based on fuels or energy limitations. The next opportunity to formally adjust force structure will occur in 2009.¹⁴⁰ Four years from now, the state of world and DoD petroleum supplies may be much more acute, at which point the DoD would likely be required to address energy efficiency and consumption as part of its force structure decision matrix. Attention to detail and proper QDR energy-related course corrections would be one of the most effective tools available to ensure the DoD reaches its goal of long-term relevancy.

QDR 2009 force structure decisions will be reaching full effect by 2020. In the proposed 40-plus year transformation strategy, the US would need to begin retiring all inefficient systems between 2020 and 2035 and activating those new 30-year systems which support a force structure deemed most effective in an energy-constrained world. In order to minimize any capability gaps between retirement of traditional systems (at the beginning of the window) and the arrival of high-efficiency and perhaps radical replacements (at the end of the window), the grand force structure strategy must maximize multi-role capabilities of remaining systems, perform cost and risk analyses of extending inefficient system life spans, and plan to accept certain mission limitations and vulnerabilities for a period, if necessary. The sooner replacements are produced, the smaller this vulnerability window will be. The US missile defense system being deployed today is a perfect example of how the earliest-

maturing technologies of a system can be spiraled into warfighter hands long before full system capability in order to mitigate enemy threats as soon as possible.

Adjusting Operational and Training Procedures

Operations and maintenance (O&M) costs—the most energy intensive portion of the budget—consume 31 percent of today's DoD funds.¹⁴¹ If the DoD is unable to deploy bridge energies before the arrival of Hubbert's Peak, the DoD will need to have adopted universal energy conservation approaches to control the volatility and size of O&M expenses. Traditional infrastructure and operating procedures will need to continue improving efficiencies, reducing footprint, and maximizing alternate energies to guarantee security and stabilize energy costs. A good example of the change is the growth in electrically powered computer training simulations that are replacing more expensive and petroleum-intense physical training events.

High energy costs may also force warfighters and national security decisionmakers to carefully select future engagements. If so, operational commanders will also be required to integrate maximum fuel efficiency and opponent energy limitations in their planning calculus. Because within 2 decades a deployed operational force may be relying upon synthetic fuels shipped from North America and shared with coalition partners, a Joint force commander may find his maneuver options limited, and in turn, driving certain, less energy-intensive courses of action. It is not unreasonable to expect the military of 2020-2035 to be forced to rely upon very lean logistics, as this dimension is typically the most energy intensive of modern warfare.

New Energy Infrastructure and Transition Technologies

Today's petroleum extraction, refinement, and distribution systems were developed and built over the course of a century. Fortunately, in today's environment, broad knowledge sharing, instant communications, rapid mass production and distribution, and large resource capital movements can enable the construction of a properly envisioned and planned new energy infrastructure in less than 100 years.

The first major infrastructure activity the DoD will have to address is incentivizing commercial development for manufactured liquid hydrocarbon fuels—this is akin to the DoD buying an energy life insurance policy and should already be executed in Stage I of the DoD's energy transformation. Without this bridge energy ensured upfront, time may run out to satisfactorily complete development of any new energy infrastructure. Because manufactured fuels can be distributed through slightly modified existing liquid fuel networks, the only area needing new investment is site extraction and refinement. The NRAC estimates that the 10 plants needed to meet the DoD's daily needs could be operational by 2020.¹⁴²

Within its current civil engineering construct, the DoD may also need to deploy a collection of smaller infrastructures that contribute to the total energy supply for both permanent and expeditionary installations. For example, as biofuel processing technology rapidly advances, it may become practical in the 2006-2020 timeframe to actually build on-site biofuel and bioelectric generation plants that utilize a base's own waste stream and surrounding biomass as raw energy sources. In addition to helping solve environmental concerns, these bioenergy plants could be produced in standardized, modular sizes from semi-truck

portable to the mega-plant, expandable to appropriately meet each base's needs. Every DoD roof and sun-facing flat surface should be covered with mass-produced, thin-film solar panels. All fluorescent and street lighting, efficient by today's standards, could be replaced by 50-plus percent more efficient LED lighting. Wind power farms subsidized by long-term DoD purchase contracts could become the norm versus the exception as they are today. Coastal bases should be able to purchase Green Energy from subsurface tidal and ocean thermal production systems facilitated by Congress and DoE with the DoD as a guaranteed buyer. If successful, this collaborative model can be repeated endlessly with any number of new concepts.

The above mentioned infrastructures (with the exception of synthetic fuels) point to a developing trend. In contrast to today's energy production at large-scale centralized facilities, distributed, on-site production has the potential to become prominent. Historically, industrial societies have produced energy at a few central locations for good reason:

- Proximity to raw energy resources
- Economies of scale
- Consolidation of limited expertise to manage the process

Unfortunately, much of the central production benefit is lost through inefficient and vulnerable distribution systems. While scientific advances are occurring with the potential to overcome these distribution inefficiencies, today's technology has also balanced the playing field, increasing the efficiencies of smaller producers, automating control and maintenance functions through computers and better design, and enabling the extraction of energy from proximate sources—much in the same manner that nature does. By “unleashing us from the tether of fuel”¹⁴³ as Lieutenant General James Mattis, USMC, has desired, DoD's forces can use the maneuver-enhancing logistical and security freedom of distributed production to offset the high mobility benefit, but precarious security, of delivered liquid fuels.

Up to this point, the subject of hydrogen infrastructure development has not been mentioned. As evidenced in the 2005 Energy Policy Act, DoE, Congress, and the President place great faith in the potential of hydrogen as the only viable large-scale, long-term replacement to hydrocarbon liquid fuels. This optimism is no doubt inspired by such recent exciting nanotech discoveries as the ability to create hydrogen from direct sunlight, enhanced electrolysis, or biological mimicry, as well as new discoveries for safer and more efficient hydrogen storage. Sufficiently researched during Stage I and later developed in Stage II, these capabilities could theoretically be used to locally produce and directly power hydrogen-fueled maneuver and mobility forces. Early and active research involvement would enable the DoD to make the earliest possible commitment toward a hydrogen-based military as a permanent replacement to temporary manufactured bridging fuels (interestingly, the technology already exists to extract hydrogen from hydrocarbons, meaning that local hydrogen production is already possible today from traditional feedstocks). To facilitate the entire three-phase strategy for energy transformation, the DoD will likely have to commit to building the necessary field infrastructure to support a hydrogen conversion by the end of Stage I, while simultaneously supporting the legacy liquid fuel system for unconverted systems. This has the potential to be the

most difficult phase of an energy transition. Fortunately, if the 2005 EPA's hydrogen technology goals are met, the commercial and private sectors will be involved in a similar pursuit, lending their accomplishments and interests to the DoD success.

The last Stage II activity would be converting selected legacy systems and early acquired modular systems to the new energy standard. This can be as simple as replacing individual components, such as lighter and more reliable linear electric actuators versus hydraulic components, or incorporating major replacements of power-generation and energy storage systems during depot overhauls. Each system would need to be assessed on a case-by-case cost-activity analysis to determine if and when such a conversion is possible—for example, conversion of hybrid HUMVEEs from a standard JP-8 fueled engine-generator configuration to hydrogen fuel cells. Unless this activity is initiated by 2020, it is unlikely that sufficient time will exist to create a fully converted and viable force for Stage III.

Stage III – 2035-2050: The New Energy Force

The DoD will see the culmination of three decades of work as it enters Stage III—The New Energy Force. To capitalize on the transformation momentum already in place in Stage II, the DoD will need to focus on:

- Completing a full conversion of all infrastructure and systems to the new energy standard.
- Ensuring distributed, ubiquitous, and adequate energy production exists to provide greater agility and survivability.
- Continuing R&D to develop even more superior forms of energy production and use. By envisioning and creating its own energy future, the DoD will be able to maintain the freedom of action and operational capability it needs to defend America's interests.

Mindful of the fact that DoE has predicted Hubbert's Peak will occur around 2037, by 2035 both the DoD and the private sector will likely be deeply involved in a large-scale conversion to the new energy. The real and environmental costs of maintaining old systems will likely rise exponentially, building the case for rapid elimination. Because of Stage I and II efforts, state-of-the-art facilities, systems, and even soldiers should by this time operate on a standard energy *bus*, relying heavily on computer optimization and networking for maximum communication and situational awareness.

As the vision for 2050 draws near, energy can be expected to be produced in a variety of ways as part of a highly distributed network (not to be confused with a centralized distribution network) and almost exclusively take one of two forms: electricity or hydrogen. It is not inconceivable that electricity will be produced by state-of-the-art coal and natural gas facilities; ubiquitous solar, wind, geothermal, thermoelectric, and ocean tide and thermal sources; various-sized nuclear plants, hydrogen fuel cells, and even on-vehicle generators. Hydrogen will be derived from water electrolysis, large scale photolysis, reformation of remaining hydrocarbon fuels, and other chemical processes. It will be either safely shipped from domestic sources, or more likely produced locally. Only in the rarest of cases will it rely on foreign fuel stocks, and then only if the risk and benefit analysis demonstrates that it is situationally more advantageous to do so. Unfortunately, aircraft systems will likely be the last to

undergo the new energy conversion, operationally restricted by power, weight, and volume constraints until technologies are most mature (remember that the DoD actually produced a hydrogen-powered jet engine as early as 1957, indicating that once hydrogen storage issues are resolved, the hydrogen aircraft may become a reality).¹⁴⁴

In the end, as the DoD and the nation grow comfortable with the new energy paradigm, and the threat of petroleum energy insecurity fades, the transition of remaining activities to the new energy standard will be self-sustaining. A new-found post-petroleum energy security and the experiences of a somewhat long and painful, but otherwise successful energy transformation, will likely enable the DoD and the nation to eventually continue pursuit of even more advanced energy concepts such as nuclear propulsion, nuclear fusion, space solar generation, moon energy exploration, and matter-anti-matter propulsion, to name a few.

As demonstrated, the journey to the DoD's energy future will be both monumental and complex, requiring enormous strategic leadership to accomplish the desired results. By using a proven transformation methodology such as Dr Kotter's eight-step process to develop a sense of urgency and the vision of the energy future it wishes to create, the DoD can then begin to dissect the scope of the problem and identify and execute the best strategy for creating the energy future it desires. To quote EIA's director, Dr Caruso, oil peaking is a problem that will occur "...within the present century."¹⁴⁵

Conclusion

From bottom to top, the military meritocracy is full of talented, dedicated and courageous people who can move out smartly to implement changes, even radical changes if they make sense and save money.

—Amory Lovins, *Winning the Oil Endgame*¹⁴⁶

The United States is the world's only superpower today because its 5 percent of the global population has transformed its personal energy and 25 percent of the world's energy resources into the economic and military might necessary to earn such a position.¹⁴⁷ By 2025, when the United States is expected to be importing 68 percent of its petroleum needs, a majority of scientists predict that world petroleum production will have already peaked or be within a decade of doing so. The global security situation associated with the arrival of Hubbert's Peak has the potential to be of a complexity and magnitude likely never before seen in the history of man. The question then becomes, how can America ensure its security in this type of scenario?

President Bush and the Congress have offered the Assured Energy Initiative and the Energy Policy Act of 2005 as starting points on the journey of eliminating American dependence on foreign oil and creating a post-petroleum economy. While mainstream attention is being focused on the Department of Energy as the logical leader in this endeavor, closer inspection reveals that DoE's charter is to specifically produce the technologies and knowledge that in turn enable a free market economy to decide the best sources and mixture of energy to power the American way of life. While a technology-intense DoD increasingly benefits from the innovations that a free market military-industrial complex provides, it has also become

A Methodology to Achieve DoD Petroleum Independence

1. Create an Undersecretary of Defense, Office of Assured Energy to serve as a guiding coalition that leads a comprehensive military energy transformation in concert with DoE Office of Science efforts to technologically facilitate a national energy transformation.
2. Develop an agreed-upon 2050 DoD energy vision.
3. Communicate vision to lowest levels in DoD, academia, industry, and others as required.
4. Build strategy *backward* from envisioned end-state; identify all requirements, subdivide and time-order technology/policy developments into manageable tasks to create a continuing series of short-term wins.
 - a. **Stage I – (2006 – 2020)**
 - i. Promote conservation by directly rewarding efficient practices and technology.
 - ii. Reform/streamline acquisition system to reward energy efficiency, adopt new standards, and support modular upgrades of developing energy technologies.
 - iii. Develop bridging energies to guarantee the energy strategy end-state timeline.
 - iv. Create and engage best minds of the nation through broad science and engineering scholarship programs and sufficient R&D funding.
 - v. Commit to the best long-term practical solutions based on research and future potential, and then establish universal standards for envisioned energy end-state.
 - b. **Stage II – (2020 – 2035)**
 - vi. Develop energy delivery infrastructure.
 - vii. Begin transition of systems and operating procedures to new energy technology.
 - viii. Press for rapid commercialization of new technologies to quickly drive down costs and inject maximum benefit into civilian society.
 - c. **Stage III – (2035 - 2050)**
 - ix. Complete employment of the *new energy* force.

Figure 10. A Methodology to Achieve DoD Petroleum Independence

dependent upon its technological tools for success. Some of these combat systems now take over 2 decades to acquire and have 40-plus year life cycles.

As America's (and likely the world's) largest single institutional petroleum consumer, the DoD has also become dependent upon liquid hydrocarbon fuels to power a unique and dominant *American way of war*, in which effectiveness is valued over efficiency to execute the National Defense Strategy. The combination of long systems acquisition lead times, an overwhelming petroleum dependence, and a nontransferable national security mission may drive the DoD into the position of being the first government agency forced to practically address the problem of Hubbert's Peak. This condition begs the question of whether an opportunity exists for the DoD to contribute toward the President's goal of creating a petroleum-free society while also ensuring it has the energy and capabilities to complete its own national defense mission to 2050 and beyond.

By applying the first three steps of Dr John P. Kotter's eight-step process for leading organizational change, this article has proposed a method in which the DoD can lead an immediate, coherent, and viable long-term strategy toward a vision of replacing petroleum as its primary energy source in order to maintain all necessary strategic and operational capability for US security to 2050 and beyond. The first step is to create a sense of urgency within the DoD that its long-term existence is threatened by rising energy costs and the prospect of declining energy supplies. The second step is to create a guiding coalition in the form of an Office for the Undersecretary of Defense for Assured Energy that possesses both the internal and interagency authority and the singular purpose necessary to lead a 45-plus year energy transformation process. Consisting of permanent representatives from OSD, the Services, and interagencies, as well as representatives of industry and academia, this group must develop and communicate the vision of a desired energy future

it wishes to create. Finally, by working backward from that desired end state, the team must then build, communicate, and execute an overarching strategy that subdivides this grand challenge into a continuum of manageable short-term goals.

Using the hypothetical vision of a 2050 US military unconstrained by conventional paradigms, this article proposed a three-stage transformation strategy to illustrate the incremental issues that will likely present themselves in a wholesale energy transformation (see Figure 10). Stage I (2006–2020) includes undertaking conservation, efficiency, acquisition, and organizational reforms; the development of bridging energies; massive R&D efforts; the establishment of new energy

standards; and identification of a primary alternate energy source most likely to be some combination of electricity and hydrogen produced from a variety of sources. Stage II (2020–2035) focuses on adjusting force structure, adjusting operational and training procedures, and creating a distributed energy infrastructure and technology transition in a modular fashion. Stage III (2035–2050) involves finishing infrastructure conversion; ensuring adequate, distributed, and ubiquitous energy production; and a continuation of R&D energy efforts.

The Department of Energy confirms that the production of petroleum will peak sometime this century—it is perhaps the most fundamental strategic problem the DoD, the US, and the world will all inevitably have to face in the next 100 years. The Kotter-based organizational change methodology presented in this article demonstrates just one approach for guiding DoD energy transformation to serve the Department's own requirements. The lessons learned and knowledge gained from such an endeavor could be reasonably applied toward a much larger national energy transformation. The DoD-to-civilian transition model has been successfully applied in other major societal changes; there is no reason to believe this grand challenge to be any different. The creation of a broadly supported post-petroleum DoD vision and transformation strategy could not only preserve a relevant military force, but also lead a positive, bipartisan, interagency, and economic demonstration for preserving American security overall. The DoD possesses the capacity to succeed in making war without oil the catalyst of true transformation.

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JL

notable quotes

Logistics is the careful integration of transportation, supply, warehousing, maintenance, procurement, contracting, and automation into a coherent functional area; in a way that prevents suboptimization in any of these activities; and in a way that permits and enhances the accomplishment of a given goal, objective, or mission.

—Lt Gen William G. Pagonis, USA

Logistics sets the campaign's operational limits.

—Joint Pub 1, *Joint Warfare of the Armed Forces of the United States*

Planning is everything—plans are nothing.

—Field Marshal Helmuth von Moltke

We need to continue the transition from a threat-based Cold War garrison force, focused on containment, to a capabilities-based expeditionary force focused on responsiveness.

—Gen Michael Ryan, USAF

Teamwork allows us to be an effective fighting force—a rapid expeditionary force capable of deploying anywhere in the world in a minimum of time and in austere conditions—not operating from where we are stationed, but from where we are needed, not when we can, but when we must.

—Gen Michael Ryan, USAF

In all war situations, the actions and decisions of command, whatever the level, are based on a blend of strategical, logistical, and tactical plans.

—Adm Henry E. Eccles, USN

The plan was smooth on paper, only they forgot the ravines.

—Russian Military Proverb

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If we don't hedge jet fuel price risk, we are speculating. It is our fiduciary duty to try and hedge this risk.

—Scott Topping, Director,
Corporate Finance, Southwest Airlines

Special Feature

In 2004, “the Office of Management and Budget (OMB) recommended that the Department of Defense (DoD) engage in a pilot program to test the utility of hedging its fuel costs.”¹ Senior OMB analysts made clear, however, that “the choice about whether or not to hedge should rest with the Department.”² DoD should

act on OMB’s recommendation and develop a strategy to include fuel hedging in its risk-control arsenal.

Developing a risk management strategy would allow DoD to hedge against unwanted budget risks. Hedging eliminates, or at least reduces, oil price volatility, smooths the budget, and improves cash management. Hedging also reduces price distortion that results from charging internal customers a *stabilized price* that does not reflect market prices and thus, does not reflect the actual cost of government purchased energy commodities.

Like DoD, the airline industry is exposed to risks associated with oil price volatility. Airline companies manage price risk using commercial derivatives markets. DoD (particularly the Air Force, since it consumes the most petroleum of all the armed Services) can learn from the airline industry’s approach.

The High Cost of Price Volatility

Every ten-dollar per barrel increase in the price of oil costs the Air Force approximately \$600M per year.³ Due to rising oil prices, the Air Force’s fuel budget for fiscal year (FY) 06 was \$800M more than FY05. The price of fuel continued to skyrocket after the FY06 budget was submitted to Congress, and as a result, the Air Force experienced another \$800M shortfall.⁴

Air Force leaders anticipated they would have to absorb the entire \$800M shortfall, in addition to the plus-up from FY05, and braced for a budget crisis. Historically, the Air Force funds unexpected expenses with an undistributed reduction across all programs, delaying the development and production of critical warfighting systems.⁵ The unexpected FY06 fuel bill was particularly crippling since the Air Force already had \$3.7B in unfunded requirements. Major General Stephen Lorenz, then director of the Air Force’s budget, admitted, “It’s an interesting dynamic. I do not know how it will play out.”⁶

The Air Force faced a similar fiscal challenge in FY05 and was forced to “slow operations [and] throttle back.”⁷ To make it to the end of 2005, the Air Force reduced readiness and pushed over \$1B in operations and maintenance bills into FY06.

Eleventh-hour budget cuts, resulting from Program Budget Directive (PBD) 723, allowed the Air Force to escape much of the financial burden from unfunded FY06 fuel costs, but the other Services were not as lucky. The Pentagon’s comptroller allocated \$1.1B in new Air Force funding, mostly to cover fuel costs, but



Fuel Hedging

Lessons from the Airlines

Lieutenant Colonel (sel) Lawrence Spinetta, USAF



Article Highlights

Financial dictionaries define hedging as making an investment to reduce the risk of adverse price movement. Fuel hedging refers to strategic actions, not necessarily just the use of derivative instruments in commercial markets, to offset commodity price risk.

In this article the author examines developing a risk management strategy that would allow the Department of Defense to hedge against unwanted budget risks. Hedging eliminates (or at least reduces) oil price volatility, smooths the budget, and improves cash management. Hedging also reduces price distortion that results from charging internal customers a *stabilized price* that does not reflect market prices and thus, does not reflect the actual cost of government purchased energy commodities.

Like DoD, the airline industry is exposed to risks associated with oil price volatility. Airline companies manage price risk using commercial derivatives markets. DoD (particularly the Air Force, since it consumes the most petroleum of all the armed Services) can learn from the airline industry's approach.

In contrast to the current approach, hedging would provide a stable budget. Policymakers would know the true cost of their budget decisions because *stabilized prices* would match actual cost. Most importantly, hedging improves cash-flow management to ensure that the necessary funds are available to meet broader corporate objectives. Hedging eliminates the need to seek

slashed \$4B in nonfuel programs from the Army, Navy, and Marine Corps budgets. Although PBD 723 was favorable from an Air Force perspective, it was far from ideal. It delayed the Airborne Laser Program and cut \$100M from the Joint Strike Fighter engine account.

The Air Force suffered less than the other Services in the budget fight to determine offsets for higher fuel costs, but it was not a budget victory.⁸ The Air Force receives no added value for paying more at the pump. Moreover, the Air Force did not escape from the fire. In other words, the Air Force continues to suffer ill effects from the rising cost of jet fuel.

Currently, the Air Force pays \$2.53 per gallon of jet fuel—a 31 percent increase from the previous year.⁹ The Air Force's FY07 budget programs fuel costs vastly below current market prices. To put this in perspective, consider the fact that the FY05 crisis unfolded when the Air Force was paying a relatively cheap \$1.74 per gallon. The Air Force will likely face another budget crisis in FY07 due to high fuel costs.

Recently, the rising cost of fuel forced one major command—Air Combat Command (ACC)—“to make significant changes just to operate.”¹⁰ To pay for unanticipated fuel costs, ACC had to reduce its flying-hour program.¹¹ The flying-hour program is based on the minimum requirements to train aircrew, so any reductions translate into a loss of combat capability and readiness. Budget analysts predict the entire Air Force flying-hour budget will need to be reduced by 10 percent each year from FY08 to FY13.

The Air Force is not alone in its concern over the adverse effects of the rising price of jet fuel. For every \$1.00 increase in fuel, the airlines collectively pay \$425M in additional operating costs.¹² Consequently, most major airlines have developed a risk management strategy and hedge some portion of their jet fuel needs. In fact, the propensity to hedge tends to be positively related to profitability and inversely related to the risk of default. In other words, the more profitable, less financially-troubled airlines tend to aggressively hedge jet fuel prices, whereas the less profitable, more financially-troubled airlines either do limited hedging or none whatsoever.¹³ For example, Southwest Airlines, the only major US airline to remain profitable since the September 11, 2001 terrorist attacks, holds the largest hedging position among carriers, with 86 percent of its jet fuel needs for 2006 capped at \$28 per barrel.¹⁴ This saves Southwest more than \$150M per quarter.¹⁵

The Air Force is not concerned with profitability, but it is concerned with managing shocks to its budget from price volatility. Fluctuations in the price of oil adversely affect the Air Force's ability to ensure the necessary funds are available to finance force modernization and fund operations. The timeline of the federal government budget cycle requires the Office of the Under Secretary of Defense (the Comptroller) to estimate and establish a *stabilized price* for fuel and other fuel-related commodities 18 months in advance of budget execution. Figure 1 diagrams the Defense Department's budget process as related to fuel. Not surprisingly, prices set by the Comptroller often prove wildly inaccurate. For example, last year the Pentagon's forecast was so inaccurate that it had to set a revised oil price that was 50 percent higher than the original price.¹⁶ The problem is that the Services' budgets use inaccurate forecasts and make budgeting decisions based on prices that are not representative of actual costs (see Figure 2).

A Bankrupt Defense Working Capital Fund

DoD is the largest single consumer of fuel in the United States, purchasing 1.8 percent of the country's total transportation fuel needs. The Defense Working Capital Fund (DWCF) is the financial vehicle that DoD uses to annually buy more than \$75B in commodities, including more than 130M barrels of fuel. The DWCF is a revolving fund that derives income from operations. Funds are available to finance continuing operations without any fiscal year limitation. Financial regulations state that fund activities will operate in a business-like fashion and incorporate full costs in determining the pricing of its products. The Comptroller establishes a *stabilized price* for oil, relying largely upon OMB forecasted crude oil prices that are based on oil futures. The Comptroller also adds *surcharges*, *costs to refine*, and *net adjustments*.¹⁷ Conceptually, the fund should break even over time. The purpose of *stabilized prices* is to provide the military with budget stability, despite price swings in commodity markets. The idea is to have DWCF reserves absorb gains or losses. In practice, however, the DWCF has neither achieved budget stability, nor protected the armed Services from inflation in oil prices.

Grossly inaccurate forecasts have repeatedly threatened the fund's solvency. Every year since 1992, Congress has either adjusted budget-year fuel prices or appropriated additional money. Mostly, *stabilized prices* have underestimated the market price of oil, resulting in large outflows of fund capital. In FY04, the administration admitted failure in its budget request, and stated, "Due to the difficulties in forecasting fuel prices 10 to 20 months in advance, this year the Administration is requesting an indefinite appropriation to cover the difference between the funds the Department budgets for the purchase of refined petroleum products and the actual market prices the Department pays for fuel (the additional marginal expense)."

Comptroller forecasts consistently prove inaccurate because oil futures are wildly inaccurate predictors of future spot prices.¹⁸ Additionally, the stabilized annual fuel prices used in the Services' budget requests to Congress do not reflect the full cost of fuel because of cash movements and inaccurate surcharges. Over \$4B was moved into and out of the working capital fund from FY93 to FY02. Congress, and to a lesser extent DoD, used much of this money to meet other priorities.¹⁹ A Government Accountability Office (GAO) report examining fuel pricing concluded, "DoD has been trying to successfully implement the working capital fund concept for over 50 years. However, Congress has repeatedly noted weaknesses in DoD's ability to use this mechanism to effectively control costs and operate in a business-like fashion."²⁰

Because the Services estimate their budgets using inaccurate forecasts, budget decisions are based on distorted prices. As a result, funds for other readiness needs are adversely affected.²¹ Underestimating oil prices results in cash outflows from the DWCF. If the forecasts grossly underestimate market prices and the DWCF is not sufficiently capitalized, the Services must scramble to obtain additional funding or take money from other programs to pay for oil price shocks.²² Overestimating oil prices means less money is available for investment. To summarize, the current approach does not "enable customers to plan and budget more confidently," in accordance with the DWCF's mandate.

Article Highlights

supplemental funding due to price fluctuation, eliminates disruptions to nonfuel programs caused by unanticipated requirements to pay higher-than-expected fuel bills, and eliminates fuel prices as a concern for DWCF management.

A prudent strategy involves hedging *incidental* risks that are beyond the Air Force's control, while retaining *core* risks that the Air Force is in a position to favorably influence. The Air Force, like the airline industry, is in the flying business, not the commodities trading business. The price of oil is clearly an *incidental* risk and therefore, it represents the type of risk which ought to be transferred. On the other hand, safety and tactics represent examples of *core* risks, which the Air Force enjoys a comparative advantage in managing.

The author concludes by noting that regardless of which hedging option is selected, DoD should implement a risk management strategy to protect against oil price shocks. Hedging allows for more effective planning and more predictable budget execution. In a sense, DoD officials are speculating by not hedging price risk. The Department of Defense should learn from the airline industry and implement a jet fuel hedging program.

Article Acronyms

ACC - Air Combat Command
DWCF - Defense Working Capital Fund
DoD - Department of Defense
OMB - Office of Management and Budget
FY - Fiscal Year
GAO - Government Accountability Office
MMS - Mineral Management Services
PBD - Program Budget Directive

The Need to Hedge

In contrast to the current approach, hedging would provide a stable budget. Policymakers would know the true cost of their budget decisions because *stabilized prices* would match actual cost. Most importantly, hedging improves cash-flow management

to ensure that the necessary funds are available to meet broader corporate objectives. Hedging eliminates the need to seek supplemental funding due to price fluctuation, eliminates disruptions to nonfuel programs caused by unanticipated requirements to pay higher-than-expected fuel bills, and eliminates fuel prices as a concern for DWCF management.

A prudent strategy involves hedging *incidental* risks that are beyond the Air Force's control, while retaining *core* risks that the Air Force is in a position to favorably influence. The Air Force, like the airline industry, is in the flying business, not the commodities trading business. The price of oil is clearly an *incidental* risk and therefore, it represents the type of risk which ought to be transferred.²³ On the other hand, safety and tactics represent examples of *core* risks, which the Air Force enjoys a comparative advantage in managing.²⁴

Hedging in Commercial Markets

The use of derivatives—financial instruments, such as options and futures contracts, which derive their value from the value of an underlying commodity, security, or index—lets investors take risk, not DoD. Thomas Siems, a senior economist and policy advisor at the Federal Reserve Bank of Dallas, notes, "Derivatives help improve market efficiencies because risk can be isolated and sold to those who are willing to accept them at the least cost."²⁵

The mechanics of hedging in commercial markets are not as complex as they seem. The majority of airlines rely on plain vanilla instruments to hedge their jet fuel costs, including swaps, futures, call options, average price options, and collars.²⁶ Zero-cost collars—buying a call option and selling a put option at the same time so income from selling the put offsets the cost of the call—are particularly attractive since they require no cash outlay and do not involve a speculative return.²⁷ It is also important to note that the value of a call option increases as volatility in

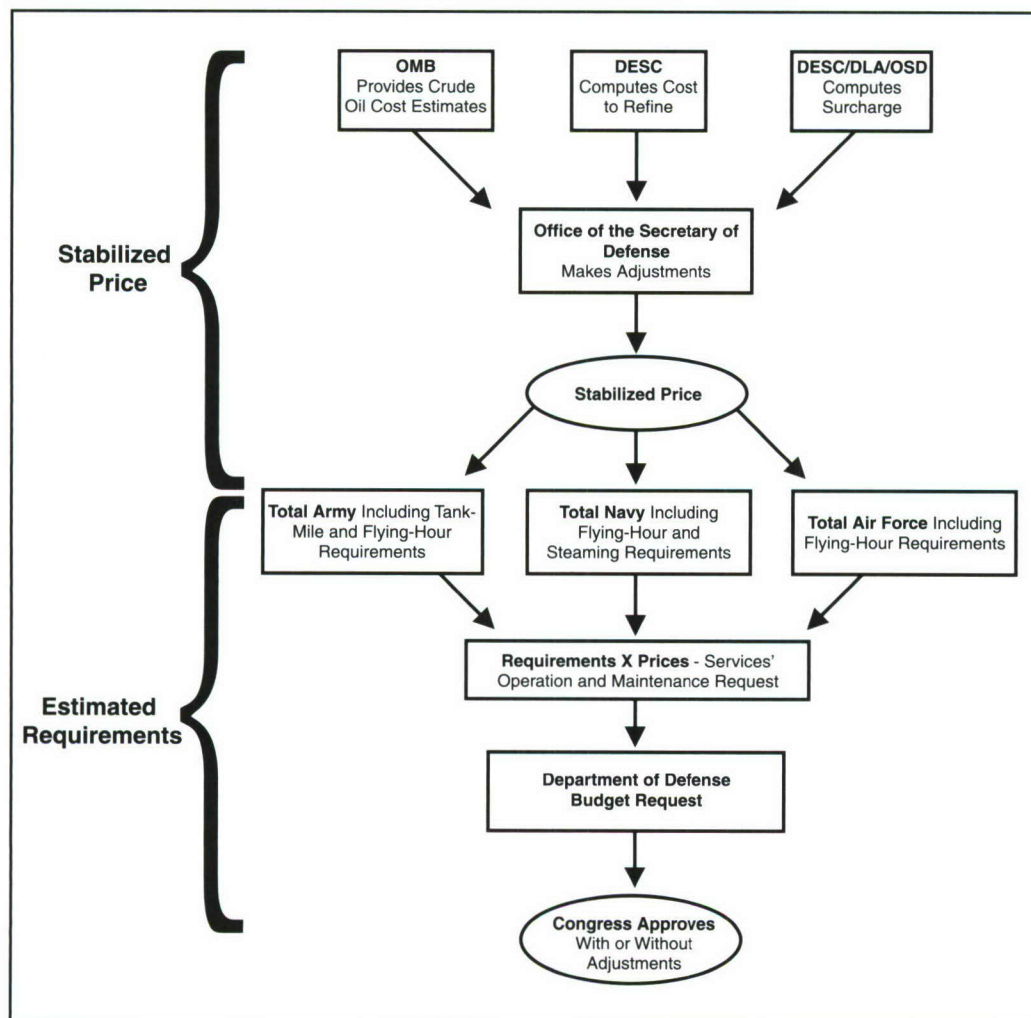


Figure 1. Budget Process for DoD Fuel

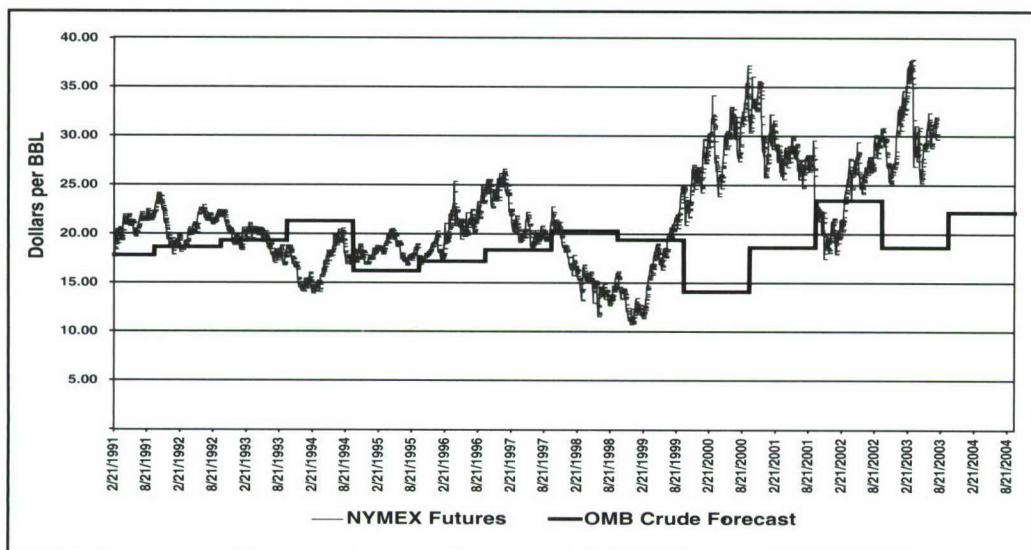


Figure 2. Crude Oil Prices Versus OMB Forecasts

the oil market increases. Because markets tend to react with trepidation when a war breaks out (especially if military action occurs in the Middle East), hedges established before a conflict starts would provide DoD with protection when it needs it most. Added to which, futures do not have the same potential counterparty risk that is endemic with the use of fixed-price contracts. Therefore, fuel support to warfighters is less likely to be interrupted.²⁸

The DoD purchases more jet fuel than any single airline, but far less than the total purchases of the largest US airlines. Delta, American, and United combined, purchase more than twice as much jet fuel as DoD. Consequently, DoD participation in commercial hedging markets would not overwhelm markets. In fact, it would improve market liquidity and hence, efficiency. Presently, the oil futures market enjoys significant liquidity for contracts up to a year. Although there is no regulated exchange for jet fuel trading, over-the-counter markets are active. Typically, airlines use rolling hedges that cross hedge price risk using crude oil and heating oil contracts to hedge price risk beyond a year. However, DoD would not need to engage in such a complex strategy because the DoD is concerned with a shorter timeline. The primary purpose for DoD hedging is to protect against budget risk and hence, the DoD is principally concerned

entitlements grow.³² In addition, the Pentagon faces an increasing population of veterans in need of health care, expensive operations abroad in support of the global war on terror, and cost growth in major acquisition programs.³³ Hedging eliminates the need for supplemental funding to cover higher-than-expected fuel prices, thereby eliminating the political liability associated with requesting additional money from Congress.

The use of derivatives in the commercial market does, however, have a potential political drawback. Because of a lack of understanding, the public may perceive DoD's use of derivatives to be a risky endeavor. The public may make unfair comparisons to scandals involving the abuse of derivatives, such as the bankruptcy of Orange County, California in 1994.³⁴ It is a myth, though, that derivatives are purely speculative, highly-leveraged instruments.³⁵ The derivatives market actually developed from a need to control risk. Proper oversight would eliminate potential for abuse. Moreover, using the appropriate techniques would further reduce risk. The purchaser of a call option, for example, only risks losing the cost of the option premium, yet enjoys unlimited potential upside.

DoD participation in commercial hedging markets would not necessarily be unique. Hedging is common practice in both private and public sectors. Businesses, from small farmers to

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with gross mismatches between stabilized oil prices and market prices during budget execution.

Airline executives know that it is often impossible to pass higher fuel prices on to passengers by raising ticket prices due to the highly competitive nature of the industry.²⁹ Similarly, the DoD is finding it increasingly difficult politically to request supplement funds from Congress to cover unexpected increases in the price of fuel. To cover the current budget shortfall, the Air Force "wants more money from OMB out of the national treasury instead of [the Air Force] having to eat it."³⁰ But, budget realities require fiscal constraint, which leads to major program disruptions. Major General Lorenz remarked,

Remember, the Air Force is just part of the national treasury and the national priorities of America. When you have a \$62.5B supplemental [to pay for the War on Terror] that wasn't even planned on, the hurricane has certainly thrown another dynamic into the budget and deficit spending and tax cuts, [you start to understand] the whole picture.³¹

Although PBD 723 gave the Air Force some relief, the Air Force should not expect a financial rescue in the future. Congress will likely be under acute pressure to curtail defense spending as the Baby Boomer generation retires and the costs of

Fortune 500 companies, rely on derivatives to hedge price risk. Some of the biggest users of derivatives are government and quasi-government agencies. Municipalities, transportation authorities, power cooperatives, and government-sponsored enterprises such as Fannie Mae, Ginnie Mae, and Freddie Mac all rely on hedges to manage risk. Mexico, Brazil, and Chile are just some of the countries that are regular users of oil derivative markets.

The Way Ahead

DoD needs to seek legislative changes from Congress to grant it the authority to establish a commercial hedging program. DoD needs to overcome three legal challenges. First, DoD has no specific authority to engage in transactions involving derivative products. DoD's general procurement is limited to products and services. Second, DoD lacks authority to derive cash benefit from liquidated positions in financial markets. Currently, proceeds from liquidated positions would go directly to the Treasury rather than into the DWCF. Third, the GAO has not addressed whether hedging budget risk is a *necessary expense* for federal agencies. DoD needs to justify the expense of a hedging program as bearing a logical relationship to the appropriation being charged.³⁶

DoD Oil Consumption Facts

- The US military, the largest single consumer of fuel in the United States, uses approximately 1.8 percent of the country's total transportation fuel.
- In FY05, the Defense Energy Support Center (DESC) purchased 130 million barrels of fuel at a cost of more than \$8 billion.
 - Seventy-five percent was for aviation fuel.
 - Fifty-seven percent was for the US Air Force.
 - Fifty-four percent of the Air Force total was for the Mobility Air Force.
- Prior to Operation Enduring Freedom and Operation Iraqi Freedom, DESC purchased approximately 100 million barrels of petroleum annually—enough fuel for 1,000 cars to drive around the world 4,620 times or 115.5 trillion miles.
- US military forces in Iraq use about 1.7 million gallons of fuel a day. On average, every soldier, sailor, and airman in Iraq consumes roughly 9 gallons of fuel a day.

An Alternative

As an alternative to hedging in the commercial markets, DoD could seek legislative authority to engage in an *intergovernmental hedging* arrangement. This option enjoys broad support from the Defense Business Board members.³⁷ They recommended DoD enter into an agreement with the Department of Interior's Mineral Management Services (MMS) group to mutually offset dollar variances resulting from fuel price volatility. By leasing both offshore and onshore energy resources, the MMS generates approximately \$4B per year in revenue. When the price of fuel increases, MMS revenues rise and DoD costs rise. When prices fall, the opposite occurs. Transferring funds from Interior to Defense or vice versa, depending on which department benefits from unanticipated price changes, would afford DoD the benefits of hedging without the cost associated with trading derivatives in commercial markets.


Conclusion

Regardless of which hedging option is selected, DoD should implement a risk management strategy to protect against oil price shocks. Hedging allows for more effective planning and more predictable budget execution. In a sense, DoD officials are speculating by not hedging price risk. The Department of Defense should learn from the airline industry and implement a jet fuel hedging program.

Notes

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notable quotes

Logistics is the bridge between the national economy and the combat forces, and logistics thus operates as "military economics" in the fullest sense of the word. Therefore, logistics must be seen from two viewpoints. Logistics has its roots in the national economy. In this area, it is dominated by civilian influences and civilian authority. On the other hand, the end product of logistics lies in the operations of combat forces. There logistics is dominated by military influence and by military authority. In this area the major criterion of logistics is its effectiveness in creating and sustaining combat forces in action against an enemy.

—Adm Henry E. Eccles, USN

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PANIC

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One of the tools available to Air Force officers to assist them in safely integrating a new program is Operational Risk Management (ORM). ORM is a six-step process based upon four primary principles—accept no unnecessary risk, make risk decisions at the appropriate level, accept risk when benefits outweigh the costs, and integrate ORM into the planning stages of an operation.

contemporary issues

Risk Analysis: F-16 Block 60 FLIR-Assisted Landing Instruction

“Risk Analysis: F-16 Block 60 FLIR-Assisted Landing Instruction” reviews the evolution of the F-16 Forward Looking Infrared (FLIR) system, specifically how the FLIR applies to the newest F-16, Block 60 under contract by the United Arab Emirates (UAE). Part 1 of this article examines the history of FLIR systems prior to the F-16 Block 60 series. Part 2 investigates the hazards associated with landing an F-16 at night, in addition to the potential utility of a FLIR-assisted landing. Finally, in Part 3, the authors present an Operational Risk Management analysis of the integration of teaching FLIR-assisted landings to new UAE Block 60 pilots. Based on this structured risk analysis, the authors recommend introducing IFTS FLIR-assisted night landings during the student’s second night sortie. This recommendation follows the logic that the student is already somewhat familiar with the IFTS from using it as a head’s-down sensor during the day. On the second night sortie, they suggest having

the student use the FLIR to identify the runway environment and then to turn the FLIR down before actually touching down. This reduces the risks of having a night landing mishap. Additionally, they suggest having the student’s first night sortie dedicated to standard night instruments and non-FLIR-assisted landings. This allows the emphasis to be on a night instrument cross-check and normal night visual landing cues, thereby giving the student a solid foundation to build his night habit patterns. If the intention becomes to teach an additional IFTS capability, extra night sorties can be added toward the end of the training program. This recommendation safely incorporates the IFTS in the initial sorties, gives a solid night instrument background to the student, and gives the flexibility to build upon the student’s IFTS procedures with additional IFTS night sorties later on in the program as dictated by the tactical requirement.

F-16 Risk Analysis: Block 60 FLIR-Assisted Landing Instruction

Gary P. Moynihan, PhD
Major Joseph Thomas, USAF

Introduction

Some of the greatest advances in infrared (IR) technology have occurred in military aviation. Through the use of IR imaging equipment, military aviators are now able to mitigate some of the risks of flying in low light and night conditions. This technology is based on the measurement of the thermal energy of an object against its background. By distinguishing small variations in thermal radiation, IR equipment can display a thermal image on a monitor.¹ This enables one to see in total darkness, through fog, and in other low visibility settings. In military aviation, this IR scene is usually displayed to the pilot on a small screen that must be referenced while flying. The result is similar to looking at a small black and white television screen commonly associated with surveillance cameras. The biggest difference is that the pilot is not seeing a representation of visible light on the display, but rather a representation of IR light and what the IR world looks like. The implications of bringing this thermal sensing capability into the cockpit are immense. Whereas before, when military aviators operated at night with decreased effectiveness due to little or no awareness of the outside horizon and surrounding terrain, IR sensors can now provide distinct scene detail of the current flying environment.

In the F-16, these IR sensors are incorporated into what is called the Forward Looking Infrared (FLIR) system. The F-16 FLIR is a *forward* sensor because it is fixed mainly to view what is directly in front of the aircraft. It is also a forward sensor in that it is displayed to the pilot through the aircraft's heads-up display (HUD). For example, the pilot is able to view an IR picture of the world by looking straight ahead without having to reference a small screen imbedded somewhere heads down in the cockpit.

This article reviews the evolution of the F-16 FLIR, specifically how the FLIR applies to the newest F-16, Block 60 under contract by the United

Arab Emirates (UAE). Part 1 of this article examines significant historical FLIRs prior to the F-16 Block 60 series. Significant predecessor aircraft, as well as conflicts in the recent past, are examined to show their impact on current FLIR philosophy. Part 2 of this article investigates the hazards associated with landing an F-16 at night, in addition to the potential utility of a FLIR-assisted landing. Finally, in Part 3, a United States Air Force Operational Risk Management analysis of the integration of teaching FLIR-assisted landings to new UAE Block 60 pilots is provided.

Background

Predecessor FLIR technology was originally developed by the United States Navy to help identify and target enemy forces.² These early systems were expensive, large, and heavy. The incorporation of modern FLIR in military aircraft was influenced both by technological progress (for example, reduction in size, weight, and cost; improvement in capabilities) and by combat necessity. In 1965, the existing combat necessity of the United States military was winning the war in Vietnam. At this point in the conflict, the enemy at the time, the Viet Cong (VC), dominated the night.³



South Vietnamese Army outposts were routinely attacked by night assaults of the Viet Cong. Even though the United States maintained a very capable air arsenal that included 149 helicopters, the VC would almost always hear the noisy aircraft. They would quickly withdraw as the helicopters approached. In an effort to affect the night war in Vietnam, a quiet observation aircraft was recommended to orbit at dangerously low attitudes above the VC at night, while observing the enemy through the use of the then current Night Optical Device technology.⁴ The result of this commission was the development of the Y0-3A Quiet Star aircraft. In January 1968, the Quiet Star arrived in theater, and soon began flying combat missions with great success. The observers in the front of the aircraft were able to identify many targets, particularly VC resupply boats moving down the Mekong River from Cambodia.⁵ These observers initially carried hand-held Starlight scopes to aid them in target acquisition.⁶ The Starlight scope evolved from technology first developed during World War II, and was based upon image intensification.

Image intensification gathers ambient light from the moon and stars and then intensifies this light. These systems operate by amplifying light in the Near IR/visible spectrum, and have led to the modern invention of night vision goggles or NVG.⁷ As the use of image intensifying technology began for military aircraft in the Vietnam War, so did the use of Mid IR sensors in military aircraft. History shows that the Vietnam War is the beginning of the split between NVG and FLIR, both of which greatly enhance night military aviation operations. The primary difference between the two technologies lies in the operating wavelengths required. As mentioned earlier, NVGs require a minimal amount of ambient visible light to be present, and that there is nothing obscuring visibility (for example, fog, smoke, dust or haze).⁸ FLIRs, on the other hand, operate solely in the middle IR range, and require no ambient light to be present. FLIRs can see in total darkness or obscured visibility.⁹

The first true FLIR was built by Texas Instruments in 1964.¹⁰ It consisted of a lens that focused IR signals on 180 helium cooled IR detectors. These detectors fed amplifiers that powered 180 light-emitting diodes. The image produced was shown on a cathode ray tube and was similar to a black and white TV picture.¹¹ As Texas Instruments was researching and developing these IR sensors in the late 1960's and early 1970's, the United States military was finding ways to put that technology to work.

Article Acronyms

FLIR - Forward Looking Infrared
FTU - Fighter Training Unit
HUD - Heads-up Display
IFTS - Internal Forward-Looking Infrared Targeting System
IR - Infrared
LANTIRN - Low Altitude Navigation and Targeting Infrared for Night
NVG - Night Vision Goggles
ORM - Operational Risk Management
TRAM - Target Recognition/Attack Multi-Sensor
UAE - United Arab Emirates
VC - Viet Cong

In 1965, the Air Force was initiating development of a low-cost guided bomb capability for its aircraft. Aiding that effort, Texas Instruments conducted a series of tests at the Armament Development and Test Center at Eglin AFB, Florida. These tests incorporated laser technology to guide free falling ordnance. This classified project received the code name PAVE and was the beginning of what would later become a series of sensors and precision-guided munitions.

The original PAVE sensors were laser tracking and laser designating pods. PAVE ARROW, PAVE BLIND BAT, PAVE FIRE, PAVE GAT, and PAVE SWORD were early examples of the Air Force using laser technology in aircraft to find and destroy targets.¹² The PAVE KNIFE system, however, represented the first attempt by the Air Force to merge a targeting system with a laser designator as part of the same avionics. PAVE KNIFE or AN/AVQ-10 was carried on the inboard pylon of the F-4D. It had a stabilized bore-sighted TV camera and a laser designator. The TV camera incorporated a low-light system for night missions but was seldom used.¹³

Combat missions using the PAVE KNIFE system began in 1968 with the 8th Tactical Fighter Wing flying missions from Ubon, Thailand into Vietnam. However, the most famous mission of F-4's using PAVE KNIFE involved the targeting of the Paul Doumer Bridge, over the Red River, at Hanoi.¹⁴ This bridge had been attacked numerous times with packages of 36 F-105s, on one occasion, and 50 F-105's on another. Those raids employed nonguided bombs, and successfully dropped spans of the bridge, but each time the bridge was repaired. On May 10, 1972, 8 F-4s with PAVE KNIFE and laser-guided bombs scored direct hits on a single span of the bridge.¹⁵ This successful raid, using relatively few resources, *hooked* the United States military on this approach. The drive was now on to build better targeting systems in concert with more precise weapons.

The Air Force quickly improved upon the targeting features of PAVE KNIFE with the introduction of PAVE SPIKE (AN/AVQ-12), which was a smaller and lighter targeting pod also designed for carriage on the F-4. The Air Force purchased 156 of them from Westinghouse between 1974 and 1979.¹⁶ Although PAVE SPIKE did incorporate new features of IR sensors and a laser range finder, this pod still had limited night capability.

The first real night attack capability came with the operational fielding of PAVE TACK (AN/AVQ-26), a targeting pod which was developed for use on F-4 and F-111 aircraft. Built by Ford Aerospace, the pod weighed 1,300 pounds.¹⁷ Although not a true FLIR, in the sense that it did not provide night time scene detail looking from the front of the cockpit, PAVE TACK did provide a useful IR picture of ground reference points and targets. The pod had two fields of view, an environment control system, and a laser designator. PAVE TACK was a large sensor, carried internally on the F-111 and externally on the F-4.

At the end of the 1970s, the United States military introduced its first FLIR for an attack aircraft on the A-6E Intruder. The Target Recognition/Attack Multi-Sensor (TRAM) debuted in 1979. TRAM incorporated a chin turret with a FLIR, a laser designator, and a laser receiver.¹⁸ TRAM was used for the delivery of unguided and guided munitions. The FLIR turret was gyro-stabilized and aligned with the laser, allowing the laser to precisely update target range just prior to unguided munitions

delivery.¹⁹ The gyro-stabilized FLIR allowed the weapon's system operator to precisely track the target after ordnance release for guided munitions delivery. This gave the A-6E the capability to maneuver after a weapon's release while at the same time continuing to guide the bomb.²⁰

The combat capabilities of PAVE TACK and TRAM came to fruition with Operation El Dorado Canyon. In April 1986, following a terrorist bombing in Europe, the United States responded by attacking Libya's ability to support and conduct such terrorist activity. For the first time in history, the United States military possessed a robust armada of precision night attack aircraft, namely the A-6E Intruder with its TRAM capability, and the FB-111 with its internal PAVE TACK system.²¹ A night attack was authorized for two distinct reasons. The first was that the Libyan MIG-25 pilots had a limited night time capability and would likely be unable to engage United States warplanes post-strike. The second was that the risk for collateral damage was minimized by striking at night because most of the civilian populace would be at home asleep. IR sensors onboard the strike aircraft, as well as laser-guided bombs, also contributed to minimizing collateral damage.

Using TRAM technology, the A-6Es evaded enemy surface-to-air missiles and antiaircraft artillery, destroyed their targets, and recovered safely home to their respective ships. FB-111s, flying at 150 meters and 834 kilometers per hour, employed GBU-10s (laser-guided 2,000 pound bombs).²² Guiding these weapons with the PAVE TACK IR targeting and laser system, the first FB-111 dropped four bombs within 50 meters of the Libyan leader's headquarters.²³ Despite the loss of two American pilots, Operation El Dorado Canyon was a huge success. Tactical advantage and surprise were achieved by operating at night. IR sensors in military aircraft were now expected, and American industry would work hard to make the next generation of IR sensors even better than TRAM and PAVE TACK.

LANTIRN, F-16, NVGs and Future IR Targeting Systems

The F-16 entered operation in the United States Air Force in January 1979.²⁴ This single-seat, multi-role fighter was originally built to be a light weight, low-cost, daytime platform. The early versions, F-16A/B Blocks 5-20, saw gradual increases in engine performance and avionics capabilities. In the mid 1980s, the F-16C/D platform debuted with the Block 25, 30, and 32s. These versions incorporated newer radars than the F-16 A/B, as well as advances in HUD and engine capability. Toward the end of that decade, General Dynamics was ready to deliver a more advanced F-16, the Block 40.²⁵ This fighter, although very similar to early F-16s, was the first single-seat platform in the Air Force arsenal to become an air-to-air and air-to-ground, night-capable fighter. This essentially meant that the Block 40 could fight its way into a hostile area using radar missiles to engage air threats, and then employ precision laser-guided bombs to destroy ground threats, all under the cover of darkness. The system allowing this night employment was called LANTIRN or Low Altitude Navigation and Targeting Infra Red for Night.²⁶

Also employed on the F-15E Strike Eagle, LANTIRN development began in 1980 at Martin Marietta's engineering facilities in Orlando, Florida.²⁷ Martin Marietta engineers began work on an external carriage system that allowed low altitude,

night, all weather, precision attack. The LANTIRN system actually included two IR sensors—one for navigation and one for targeting. These sensors were located in two separate external pods. The AAQ-13 navigation pod housed a terrain-following radar in addition to its FLIR.²⁸ Unique to the F-16 Block 40, the navigation pod FLIR provided the first wide field of view for air-superiority fighters.²⁹

The Block 40 had an expanded HUD and had the ability to superimpose the navigation pod's FLIR image through the HUD. The result was that the pilot was presented an IR image of the surrounding terrain as seen through the nose of the aircraft. The AAQ-14 targeting pod was used to identify and destroy ground targets by utilizing a FLIR and a laser designator to illuminate the target for laser-guided bomb deliveries.³⁰ The targeting pod worked in conjunction with laser-guided munitions much like the earlier PAVE TACK system on the F-4 and F-111. The IR picture of the target was presented to the pilot on a heads-down display along with crosshairs for aiming the laser.

At the time, LANTIRN provided the Air Force with a single-seat fighter capable of operating at night only a few hundred feet altitude under the protection of the navigation pod's terrain-following radar. The pilot was able to stay visual with his flight lead, even lights out, by flying in trail and referencing the FLIR through the HUD. Two F-16 Block 40s flying in this formation at night could actively search for air threats using their radar, stay visual with each other using the FLIR, stay protected in the low altitude environment using the terrain following radar, and drop precision-guided munitions on the target using the targeting pod. With the Block 40 LANTIRN system, advances in FLIR fighter capability had finally yielded a highly survivable, highly lethal, relatively low cost (as compared to the F-15E and FB-111), night-capable, single-seat fighter aircraft. The Air Force would take delivery of 265 F-16 Block 40s as the military conflicts of the 1990s loomed on the horizon.³¹

During Desert Storm, only the navigation pod was operational on the F-16. Military commanders still employed the Block 40 to ground targets. However, the F-16 achieved limited success. Trained for the bad weather scenarios in Europe, and against a Soviet threat, the Air Force now found itself able to work at higher altitudes away from certain ground threats while still dropping precision-guided ordnance. The Block 40s at the time attempted medium altitude unguided bombing referencing the FLIR for target acquisition. This did not enjoy nearly the success rate of the precision-guided delivery platforms.³² The overall success of employing precision-guided munitions at night in the medium altitudes, however, would carry into Air Force doctrine after the conflict. The Air Force would continue to exploit its nighttime capability while at the same time reducing requirements to employ in the low altitude environment. The direct result was a decreasing need for LANTIRN's navigation pod as well as an increasing demand for the targeting pod.

From 1996 to 1997, the Air Force removed the operational need for F-16 Block 40 pilots to use the terrain-following radar. LANTIRN units then carried the navigation pod for its FLIR function only. However, due to FLIR's limited field of view, units gradually embraced NVGs. NVGs offered a higher degree of flexibility over the navigation pod. While the navigation pod showed a fixed FLIR image through the nose of the aircraft, NVGs were mounted to the pilot's helmet and could move as the helmet moved.

The Army had continued to advance night vision goggle technology and in the 1980's began fielding NVGs in their helicopters with great success.³³ The Air Force took notice, and by 1997, had incorporated NVG instruction into its training facility for the F-16 at Luke AFB, Arizona.³⁴ Using NVGs and targeting pods, the F-16 Block 40 from Aviano AB, Italy, saw combat in Bosnia and Kosovo. Shortly thereafter, all Block 40 units ceased flying with the navigation pod altogether.

The use of the combined two-pod LANTIRN system has become progressively more limited, although it is still available for foreign military sales.³⁵ However, IR targeting systems have become a fighter aircraft staple. F-16s, other than the Block 40, began to fly and employ with IR targeting pods. Air National Guard Block 25, 30, and 32 F-16s successfully incorporated Northrop Grumman's Litening Targeting Pod System. Litening had improvements over the Block 40 targeting pod that included a black and white TV tracker and improved IR resolution and close-in field of views.³⁶ Litening has successfully proven itself in Afghanistan and Iraq.

In an effort to further increase its IR targeting fighter capability, the Air Force is currently developing the third generation of FLIR pods. The Air Force now wants FLIR pods to operate at higher altitudes (up to 40,000 feet above mean sea level), and provide close resolution IR target detail from greater standoff ranges (up to 20 nautical miles slant range).³⁷ Companies who manufacture the newest IR pod include Raytheon's ATFLIR, Northrop Grumman's Litening II, and Lockheed Martin's Sniper pod.³⁸

Currently, the Air Force and Air National Guard have selected the Sniper pod as an avionics update for the F-16.³⁹ Sniper offers a significant reduction in drag and weight compared to the Block 40 targeting pod. It also incorporates a third generation mid-wave FLIR, dual laser modes, a black and white TV tracker, a laser spot tracker, and a laser spot marker.⁴⁰ The Air Force started taking delivery of Sniper pods in 2003. The Sniper is expected to be the last external IR targeting system.⁴¹ Future fighter jets such as the F-22 and Joint Strike Fighter will likely contain some type of internal targeting system.

IFTS and the Block 60

Even though IR targeting systems and NVGs have become the accepted baseline for fighters over the last decade, the navigation FLIR did not completely disappear. In 1987, Lockheed Martin conducted a series of test flights with a nose-mounted FLIR. This program was called Falcon Eye, and it incorporated a nose-mounted FLIR and a helmet-mounted display.⁴² This revolutionary technology involved mounting a small FLIR on top of the radome of an F-16. The FLIR was slaved to movements of the pilot's helmet. The FLIR image was then projected into the visor of the helmet-mounted display. In essence, this allowed for truly turning night into day. Wherever the pilot looked, he could see a FLIR image of the surrounding terrain filling his visor.⁴³

There are two notable aspects about the Falcon Eye program. First, mounting the FLIR on the top of the radome (just forward of the canopy), made the FLIR more in line with the pilot's actual head position. Second, using a FLIR-projected image in the visor meant that the sometimes cumbersome NVGs were not needed. In the late 1990s, a variation of the Falcon Eye program was incorporated into the latest F-16 to roll off the assembly line (the Block 60).

On 25 May 1999, the United States approved the United Arab Emirates (UAE) to buy 80 F-16 Block 60 aircraft. This was an \$8B sale, with an additional \$3B in research and development funded by the UAE.⁴⁴ Block 60 promises to deliver several new capabilities that current F-16s do not have. Some of the bigger advancements include the Block 60's conformal tanks (fuel tanks conforming to the fuselage above the wing to increase flying range), an agile beam radar with an electronically scanned antenna, and the Internal Forward-Looking Infrared Targeting System (IFTS).⁴⁵

The IFTS appears similar to the Falcon Eye design. While IFTS does not incorporate a helmet mounted sight nor a FLIR slaved to the pilot's head movement, it does resemble Falcon Eye's nose mounted FLIR. Designated the AN/AAQ-32, the IFTS has both internal and external IR sensors. The navigation FLIR is a wide angle FLIR turret mounted just forward of the cockpit, and the targeting FLIR is an external sensor mounted underneath the engine intake.⁴⁶

Hazards of F-16 Night Landings

A fighter training unit (FTU) is the third step in fighter pilot instruction. First, a student learns to aviate during a year of basic pilot training. Next, for those that will fly fighters, there are several months of advanced training introducing fighter tactics with less advanced platforms. For the F-16, the first time a new pilot operates this aircraft is at FTU. FTU training is generally separated into daytime takeoffs and landings and then into daytime tactics. Similarly, night training is separated into nighttime takeoffs and landings. Night tactics are subsequently introduced. The availability of the Block 60 IFTS for a student pilot's initial night sorties initiates consideration of including IFTS operation as part of their basic night landings.

To help understand the historical hazards of night operations in the F-16, five current instructors at the 162^d Fighter Wing, Tucson Air National Guard were interviewed. These pilots were selected because of their previous experience with LANTIRN as well as their knowledge of teaching night landings at the Tucson FTU. Three questions were posed to each instructor. The were asked to describe:

- Local hazards for night landings in the F-16
- Use of the Block 40's navigation pod FLIR for taxi and landing
- Any F-16 night-landing mishap with which they were familiar

The following is a summary of F-16 night-landing mishaps learned from these interviews.

Four F-16 mishaps at night were detailed in these interviews. Two involved using the FLIR to help land and two did not. The first mishap described happened at an overseas base while landing at night. The approach was to the south, and just short of the runway was a valley with lower terrain than the landing surface. This created the illusion that the F-16 was high on glide path. The valley also produced a thick fog that crept up to the threshold of the runway and obscured visibility in the initial landing phase. With fog obscuring the landing zone, the pilot perceiving that the jet was above glide path, and no FLIR available to assist, the Air Force lost an F-16 when it crashed short of the runway.

A similar event happened at a continental United States F-16 base. The pilot was only able to get a few sorties prior to the event

and was therefore not as proficient at night operations when the mishap occurred. On recovery to landing, the runway assigned was the opposite from the landing surface where the pilot was accustomed to landing. This particular runway had few city and other natural lights. This situation then created a black hole effect where the pilot had few visual cues to tell that he was descending. On this mishap, low proficiency, vectors to an unexpected runway, a black hole effect on short final, and no FLIR available to assist, all combined to produce a low situational awareness for the F-16 pilot. The result was a very hard landing followed by main landing gear failure.

The next two accounts involve emergency F-16 diverting to strange fields using the FLIR to assist. In the early 1990s, an F-16 flying a night low-level mission developed an engine oil problem. This particular low level was in Arizona, and the nearest divert for the pilot was the city of Kingman. Kingman's runway was not controlled at night and was a shorter-than-normal landing surface for the F-16. Using the F-16 navigational waypoints to find the airfield, the pilot then used the FLIR of the Block 40 to line up and land uneventfully on this short airfield. Further, the entire airfield was blacked out, with no lights on the runways or taxiways. A similar event also happened during an emergency divert due to an engine oil problem. This time, the aircraft was in Saudi Arabia on a night mission when the problem developed.

Currently, the Air Force and Air National Guard have selected the Sniper pod as an avionics update for the F-16. Sniper offers a significant reduction in drag and weight compared to the Block 40 targeting pod.

The airfield chosen for divert was entirely blacked out, and the pilot successfully used the FLIR to line up and land uneventfully.

In each of these four accounts, the pilots involved were fully qualified in the F-16. None were beginners in an FTU environment. In the case of the fog landing, it is not certain if the runway threshold would have been adequately indicated on the display. The end result might have been the same. But in the case of the hard landing, utilization of a FLIR may have changed the outcome. At minimum, having the FLIR turned on would lessen the black hole effect on short final by providing an IR picture of the runway environment. Conversely, the FLIR could also have led to a low situational awareness because it is another sensor which must be turned on, adjusted, and cross-checked. In this case of low proficiency, adding another sensor only increases pilot workload and may be more of a distraction than a help. FLIR utilization then is not an overall solution to preventing night-landing mishaps in the F-16, but rather another tool that can be used to enhance situational awareness.

In trying to address whether or not utilization of the Block 60 FLIR should be applied at the FTU level for night landings, investigation into how the Block 40 FLIR was taught might provide some insights. As a former instructor at the LANTIRN FTU, one of the coauthors recalls how the navigation FLIR was introduced, and how it was used to assist in night landings. First, LANTIRN pods were withheld from the upgrading fighter pilot until that pilot was a graduate of FTU. Then, the new pilots going to Block 40 F-16 assignments were enrolled in a short top-off

course to teach them the LANTIRN system. This course consisted of a week of academics to learn the systems and then 2 weeks of flying to accomplish four specific training missions. At the end of this course, the pilot was fully qualified to employ in the night medium altitudes using the LANTIRN systems. The pilot did not graduate from this program with a terrain-following radar qualification. To introduce the FLIR in flying operations, students were required to turn the FLIR on during ground operations, tune the FLIR to current atmospheric conditions, and observe the FLIR through both the heads-up display (HUD) and the heads-down display during taxi. The FLIR was turned down in the HUD for takeoff, turned back up for the mission, and turned back down for landing.

The reasons for turning the FLIR up and down in the HUD have to do with where the navigation pod was mounted, as well as the instructor pilot's ability to monitor (from the backseat) the student pilot's landing. The navigation pod was installed just abeam the bottom left side of the engine intake in the Block 40. Due to its proximity to the ground, this pod presented a distorted picture of the taxi speed when viewed from the HUD. When the FLIR was imposed in the HUD during taxi, the pilot erroneously sensed a much higher rate of movement across the ground during normal taxi speeds. As the upgrading pilot turned the FLIR down and not off in the HUD, he would no longer see the FLIR image

superimposed, and therefore not obtain false ground rush features, while at the same time the instructor in the back would be able to call up the FLIR image in his heads-down display and would be able to monitor the student's progress.

This method was particularly useful for monitoring the student's landing at night. The student would fly his normal instrument approach until obtaining visual cues with the runway, consistent with FTU training without a FLIR. The instructor pilot, meanwhile, could watch the runway through the FLIR and confirm that the landing area was clear, quickly process the student's expected point of touchdown, and get a sense of aircraft height above the ground. All of these cues were invaluable for providing better instruction as well as increasing the safety aspect of monitoring the landing.

On the third ride in the program, the student was instructed to leave the FLIR up in the HUD on recovery and, in essence, conduct a FLIR-assisted landing. The underlying instructional concept was that by the third ride, the student was more comfortable operating the FLIR, was fairly current in night landings, and still had an instructor pilot in the backseat to quickly help if any problems arose. Once established on a precision approach final, from about 10 miles out and a few thousand feet in altitude, the student would look through the HUD with the FLIR up and attempt to identify the runway environment while primarily referencing the aircraft instruments. If the runway environment was not quickly identified, the teaching emphasis among instructors was to stay on the

instruments and fly the approach. Most students could see the landing runway in the FLIR somewhere between 10 and 5 miles out from landing. Regardless of when, or even if, this FLIR ID happened, under no circumstances would the student be allowed to leave the FLIR up for the actual landing. The runway's green, red, and yellow visible lights coupled with the FLIR's IR depiction of the real lights created for a fairly bright HUD. In this situation, one of the first things to get overloaded was usually the pilot's depth perception. This potentially could lead to dangerous situations of a high flare, or an incomplete flare. Therefore, the FLIR was used to assist in finding the runway environment, but was never actually used in the landing phase.

Application of Operational Risk Management

One of the tools available to Air Force officers to assist them in safely integrating a new program is Operational Risk Management (ORM). ORM is a six-step process based upon four primary principles—accept no unnecessary risk, make risk decisions at the appropriate level, accept risk when benefits outweigh the costs, and integrate ORM into the planning stages of an operation.⁴⁷ Since the Block 60 had not yet arrived at the 162nd Fighting Wing at the time of this writing, the principle of placing ORM in the planning stages is met by conducting this analysis. The other three principles are addressed by a discussion of the steps as depicted below.

Based on this structured risk analysis, the recommended option is to introduce IFTS FLIR-assisted night landings during the student's second night sortie. This recommendation follows the logic that the student is already somewhat familiar with the IFTS from using it as a head's-down sensor during the day.

The first step is hazard identification. To assist in this step, interviews were conducted with 162^d instructor pilots asking them to identify hazards for night landings in the F-16. One instructor indicated that the canopy glare from bright approach lights on Runway 11L at Tucson International Airport is a distraction, that the opposite runway, Runway 29R, has very little lighting, and that currently the 162^d conducts many night landings with young students with very few cues available to the instructors for safely monitoring from the backseat. Three other instructors interviewed also mentioned a lack of approach lighting to Runway 29R at Tucson as being a potential hazard. In addition, it was indicated that using the IFTS FLIR could prove to be a distraction to the young pilot who is still trying to develop a non-FLIR normal sight picture for an F-16 night landing. Another potential hazard of the IFTS FLIR is that the young pilot could abandon cross-checking his aircraft instruments and rely solely on this visual picture. This hazard could include mistaking the landing surface for the parallel runway or taxiway, or getting dangerously low on final by not flying the instrument approach.

After reviewing the hazards, the next step concentrates on assessing the risk—that is, an aircraft could have a landing

accident. There are four degrees of severity of risk using the ORM model: catastrophic, critical, moderate, and negligible.⁴⁸ Defining catastrophic as complete mission failure, death, or loss of system,⁴⁹ having a landing accident, at a minimum, results in the loss of that aircraft while it gets repaired. Therefore, the severity of this risk is categorized as catastrophic. Subsequently, a probability assessment is conducted. Night landing accidents occur very rarely, but all pilots are exposed to this risk. Following the ORM model, an unlikely probability coupled with a catastrophic severity yields an overall risk assessment of medium.⁵⁰

The next ORM step, after accurately weighing the risk, is to seek methods to control that risk. The goal in this step is to find ways to reduce or eliminate the probability, severity, or exposure of the risk.⁵¹ In this situation, the worst severity is already paired with the lowest probability. As previously mentioned, it is not likely given the nature of aircraft landing mishaps. Further, all FTU students are required to accomplish night qualifications. Thus, the risk exposure cannot be reduced. Therefore, the only adequate control measure is to attempt to reduce the severity of the risk. With regard to the hazards mentioned in Step One, having a FLIR available to the instructors in the backseat would actually remove some of the hazards. During an approach to Runway 29R, using a FLIR on final would lessen the effect of

having few visual lighting cues prior to the runway threshold. In addition, the instructor would be able to monitor the student's landing more effectively by referencing the FLIR on the heads-down display.

Consideration must then be given to reducing risk by using the FLIR for the entire landing phase. Unlike the external Block 40 FLIR pod, which was never available to students during their basic FTU qualification, the Block 60 IFTS FLIR is internal and will be available for use on the student's very first sortie. This is important because, most likely, students will become somewhat familiar with the FLIR operation well before their first night sortie. Instructor pilots in the back seats of the first transition sorties will undoubtedly have the students at least turn on the FLIR. This is because having the FLIR up as a heads-down display in the rear cockpit will allow the instructor to better monitor the student's landing, even during the day. This leads back to the issue of allowing the student to leave the FLIR up in the HUD on his first night sortie.

There is precedence for landing with a FLIR, all the way through touchdown. The Air Force test community did just that with the Block 40 FLIR in the late 1980s. At Edwards AFB in

the 1988-1989 timeframe, Air Force test pilots practiced landing at completely unlit airfields primarily referencing the FLIR. The landings were a fairly common occurrence and the teaching emphasis of new test pilots learning this technique was not to flare too high. Because of the low pod elevation, seeing an unlit runway in the HUD with the FLIR made the landing surface appear closer than it was in real life. Although there is no official basis as to why the technique was never incorporated in the FTU, practicality appears to be reason. Block 40 operational pilots never landed with the FLIR up in the HUD. They knew it was there if it was needed in an emergency, as in the two successful FLIR landings discussed earlier in this article, but it posed more of a risk than a benefit on routine night landings. Unlike at Edwards AFB, every approved airfield for F-16 operation at night is an instrument airfield with proper airfield lighting and an instrument approach. Having a FLIR up with normal runway lighting is likely to cause disorientation, as described earlier. Obviously, Air Force test pilots had the authorization as well as access to airfields where the lights could be turned off.

Although there is precedence for FLIR landings in the F-16, the benefits do not appear to outweigh the risk for the young pilot. Test pilots are carefully selected after years of flying their primary weapon system and have previously learned the proper sight picture of how to land at night. Student pilots in FTU have not yet learned that proper sight picture. To allow a student to integrate immediately with the IFTS FLIR at night is a failure of the FTU training program to ensure that the student has mastered the basic night landing flying skills. Using a FLIR in FTU will simultaneously reduce some risks and increase other risks associated with a night-landing mishap. The solution is most likely a compromise between when to use the FLIR and when to turn it off in the HUD. Those decisions are applied in the next ORM step.

Step Four of the ORM process is to make control decisions (for example, where the decision must be made as to which control course of action should be pursued).⁵² Ultimately, this is where judgment is applied to see if the benefits outweigh the risks. In this case, the decision is where and how to integrate the FLIR into Block 60 night operations. If the Block 40 LANTIRN model is used, one option is for the upgrade student not to use the IFTS until the end of the basic program. By then, the student would have already had a few rides at night and would have made some landings without the use of a FLIR. The benefit here is that the student would first learn a non-FLIR-assisted landing sight picture and then build upon that sight picture later with the IFTS upgrade.

In comparison, student pilots in the previous UAE FTU course accomplished two night rides. The first ride consisted of night instrument approaches and landings and the second consisted of night air-to-air refueling, and then night intercepts. If the Block 40 model is adopted, these two rides would still be in the training flow. Extra rides would be added at the end of FTU to teach IFTS. In this case, there would be an increase in cost for the slightly longer course and the additional instructor pilot support required to teach the extra IFTS rides.

Another option is to introduce the IFTS during the basic FTU training program. In this case, the recommendation is to have the student's first night sortie be without using the FLIR. Here basic night instrument approaches and night landings would be emphasized. On the second sortie, fuel and time should be

reserved for the end of the intercept mission to allow two instrument approaches. Once again following the Block 40 model, the emphasis should be placed on FLIR-assisted landings, using the FLIR to help identify the runway environment and then turning it down in the HUD for the actual landing.

If more advanced tactics are taught later in the program with the targeting IR portion of IFTS, then the FLIR-assisted landing sight picture could continue to be built upon. Both of these are sound options for reducing the risk of IFTS integration at the FTU level. The decision of which to follow will be influenced by the current unknown of how many additional night sorties are required to teach the full capability of IFTS. It is these authors' opinion that at least two additional night sorties will be required to teach the ground attack capabilities of IFTS. That would make a total of four night sorties required in the UAE FTU.

After choosing either option one or two above, the ORM process includes two final steps. These steps, however, are not addressed in this article since the Block 60 IFTS had not yet arrived on station at the time of writing. Once a night training plan is agreed upon by the leadership, and the jet is actually in place and conducting training sorties, then the next steps of implementing risk controls and supervising will be pertinent.

Conclusion and Recommendation

This article examined the history of IR sensors most influential to the F-16, and a pilot's perspective on the hazards of landing the F-16 at night. An Air Force ORM was then conducted as to the feasibility of integrating the Block 60 IFTS into an FTU environment. Based on this structured risk analysis, the recommended option is to introduce IFTS FLIR-assisted night landings during the student's second night sortie. This recommendation follows the logic that the student is already somewhat familiar with the IFTS from using it as a heads-down sensor during the day. On the second night sortie, it is recommended to have the student only use the FLIR to identify the runway environment and then to turn the FLIR down before actually touching down. This reduces the risks of having a night-landing mishap. Additionally, the student's first night sortie is recommended to be dedicated to standard night instruments and non-FLIR-assisted landings. This allows the emphasis to be on a night instrument cross-check and normal night visual landing cues, thereby giving the student a solid foundation to build his night habit patterns. If the intention becomes to teach an additional capability of IFTS, extra night sorties can be added toward the end of the training program. This recommendation safely incorporates the IFTS in the initial sorties, gives a solid night instrument background to the student, and gives the flexibility to build upon the student's IFTS procedures with additional IFTS night sorties later on in the program as dictated by the tactical requirement.

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notable quotes

Be nice to your mother but love your logisticians and communicators.

—Gen Charles A. Horner, USAF

You think out every possible development and decide on the way to deal with the situation created. One of these developments occurs; you put your plan in operation, and everyone says, "What genius..." whereas the credit is really due to the labor of preparation.

—Marshal of France Ferdinand Foch

INSIDE LOGISTICS

EXPLORING THE HEART OF LOGISTICS

A Tabu Search Approach to the Strategic Mobility Mode Selection Problem

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Introduction

The efficient and effective solution to the Strategic Mobility Mode Selection Problem (SMMSP) is essential to the effective and efficient force projection of the US Military. The SM Mode Selection (SMMS) process assigns a transportation mode to personnel and materiel for shipment from CONUS to OCONUS. A foundation of the National Military Strategy¹ is to maintain most forces in CONUS while being

prepared for OCONUS missions.² On demand, a previously constructed plan, the mission's time-phased force deployment data (TPFDD)³ is executed to move specified personnel and cargo to designated locations. A TPFDD stipulates the timely deployment of personnel and cargo to the best mission locations.

The next section describes the basic SMMSP, presents a small example, and outlines the objectives of the research documented in this article.

The SMMSP

The TPFDD's sequence and timing is critical not only to mission accomplishment, but also to the safety of personnel and cargo in an OCONUS operational area or port of debarkation (POD). The multitrip reuse of aircraft and ships traveling from ports of embarkation (POE) in CONUS to OCONUS PODs and the presence of time window constraints, as described below, causes the SMMSP to be a variant of the vehicle routing problem with time windows.⁴

Other TPFDD restrictions such as the CONUS origin ready to load date (RLD), POE available load date (ALD), POD earliest arrival date (EAD), POD latest arrival date (LAD) and final destination required delivery date (RDD) are also present. These dates are time sequenced and are often mutually dependent. The RLD, ALD and EAD are hard constraints. The LAD and RDD are soft constraints.

In SM modeling, early completion is only one part of a multicriteria objective. A primary goal of an SM model is to meet the LADs. As presented in Figure 1, any arrival between the EAD-LAD time window is sufficient. It is also desirable to minimize vehicle usage, especially aircraft use. If the LADs cannot be met, a secondary objective, minimizing lateness (violations of LADs) and required resources, is invoked.

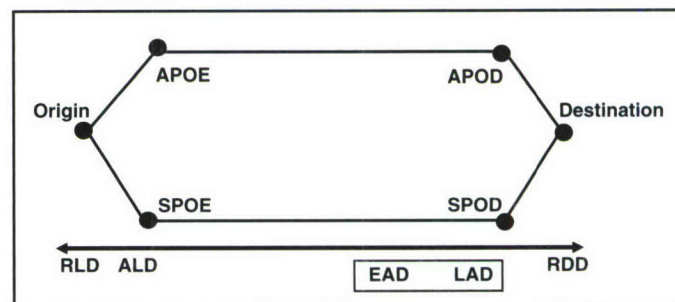


Figure 1. Strategic Deployment Timeline

Article Acronyms

AFRP - Aerial Fleet Refueling Problem
AFCSP - Aerial Fleet Crew Scheduling Problem
ALD - Available Load Date
ATS - Adaptive Tabu Search
CONUS - Continental United States
DANTE - Deployment Network Tool Extended
DoD - Department of Defense
EAD - Earliest Arrival Date
GDAS - Global Deployment Analysis System
JFAST - Joint Flow and Analysis System for Transportation
LAD - Latest Arrival Date
MIDAS - Model for Intertheater Deployment by Air and Sea
MobSim - Mobility Simulation Model
OCONUS - Outside the Continental United States
PAX - Passengers
POD - Port of Debarkation
POE - Port of Embarkation
RDD - Required Delivery Date
RLD - Ready to Load Date
RLN - Requirement Line Number
RTS - Reactive Tabu Search
SAP - Strategic Airlift Problem
SMMS - Strategic Mobility Mode Selection
SMMSP - Strategic Mobility Mode Selection Problem
STQL - Strategic Transportation Quick Look
TDVRSP - Theater Distribution Vehicle Routing and Scheduling Problem
TPFDD - Time Phased Force Deployment Data
TS - Tabu Search
USTRANSCOM - United States Transportation Command
WBP - Wide Body Plane

RLN	Description	PAX	Bulk	Over	Out	Orig	RLD	POE	ALD	POD	EAD	LAD	M	Dest	RDD
05AAL	2/160TH SOAR ABN 2 MH47	40	273	395	206	CYWF	0	CYWF	0	JEAH	100	100	A	JEAH	100
05AAF	HHC ABN SF GROUP (HQ ADVON)	132	712	274	274	HDBL	13	CYWF	13	JEAH	13	14	A	JEAH	14
05BB	SOF CMDR USAF COMAFSOF HQ ELE	44	20	0	0	FTEV	0	FTEV	0	FUQN	1	1	A	FUQN	1
05BD	SOF 04 MC130E 8 SOS	83	206	159	0	FTEV	0	FTEV	0	FUQN	1	1	A	FUQN	1
05BKB	MIB CEWI ABN CORPS GRV	6	181	0	0	LEXG	6	LEXG	15	JEAH	28	32	A	JEAH	32
5BKD	MIB CEWI ABN CORPS GRV	415	302	0	0	LEXG	6	LEXG	15	MQNA	27	31	A	MQNA	31
00AJ	STINGER MISSILES	0	168	0	0	HCTL	0	QKJA	12	JEAH	12	25	A	JEAH	25
00DDA	HQS HQS CO SPT BN ABN	95	0	0	191	HCTL	8	TMKH	18	JEAH	24	26	A	JEAH	26
00JCC	AR CO AR BN ABN DIV/SEPBD	20	0	0	191	HCTL	0	TMKH	12	JEAH	12	22	A	JEAH	22
00KB	HHC MED HEL BN CH 47	68	80	1490	160	HFTZ	0	UHGN	0	JEAH	0	9999	A	JEAH	9999
02CB	MICOM RESUPPLY	0	0	1728	0	CWFA	15	XQDT	16	JEAH	16	20	S	JEAH	20
00BE	AVN MAINT CO AASLT	150	210	3282	0	HDBL	0	CYWF	13	JEAH	13	18	P	JEAH	18
01AAC	CORPS FINANCE GROUP	0	80	160	0	HCTL	6	ZBES	18	FTZH	24	26	P	FTZH	26
00KCC	HHD AIR TRAFFIC CONTROL B	0	100	829	1480	HFTZ	0	LCMT	0	FTZH	0	9999	S	FTZH	9999
00GDC	AR CO AR BN ABN DIV/SEPBD	0	0	0	191	HCTL	0	ZBES	12	FTZH	12	22	S	FTZH	22
00FTC	FWD COMM CO ABN	0	341	108	0	HCTL	0	ZBES	18	FTZH	24	28	S	FTZH	28
05BC	SOF 04 HC130	48	460	0	0	FUQN	0	FUQN	0	FUQN	1	1	X	FUQN	1

Table 1. SMMSP Example

RLN	Description	PAX	Bulk	Over	Out	Orig	RLD	POE	ALD	POD	EAD	LAD	M	Dest	RDD
05AAL	2/160TH SOAR ABN 2 MH47	40	273	395	206	CYWF	0	CYWF	0	JEAH	100	100	A	JEAH	100
05AAF	HHC ABN SF GROUP (HQ ADVON)	132	712	274	274	HDBL	13	CYWF	13	JEAH	13	14	A	JEAH	14
05BB	SOF CMDR USAF COMAFSOF HQ ELE	44	20	0	0	FTEV	0	FTEV	0	FUQN	1	1	A	FUQN	1
05BD	SOF 04 MC130E 8 SOS	83	206	159	0	FTEV	0	FTEV	0	FUQN	1	1	A	FUQN	1
05BKB	MIB CEWI ABN CORPS GRV	6	181	0	0	LEXG	6	LEXG	15	JEAH	28	32	A	JEAH	32
05BKD	MIB CEWI ABN CORPS GRV	415	302	0	0	LEXG	6	LEXG	15	MQNA	27	31	A	MQNA	31
00DDA	HQS HQS CO SPT BN ABN	95	0	0	191	HCTL	8	TMKH	18	JEAH	24	26	A	JEAH	26
00JCC	AR CO AR BN ABN DIV/SEPBD	20	0	0	191	HCTL	0	TMKH	12	JEAH	12	22	A	JEAH	22
00KB	HHC MED HEL BN CH 47	68	80	1490	160	HFTZ	0	UHGN	0	JEAH	0	9999	A	JEAH	9999
00BE	AVN MAINT CO AASLT	150	210	3282	0	HDBL	0	CYWF	13	JEAH	13	18	P	JEAH	18
05BC	SOF 04 HC130	48	460	0	0	FUQN	0	FUQN	0	FUQN	1	1	X	FUQN	1

Table 2. Pressurized Air Transport

A TPFDD is presented at six different levels of detail.⁵ The tabu search (TS) method documented here provides asset level visibility and operates at TPFDD Level 3. The generic reference to a TPFDD item is a requirement line number (RLN). All passengers (PAX) *must* be transported by air. Cargo not transportable by air is restricted to ships. Most items may be

assigned either mode and the most appropriate should be selected. After RLN mode selection is completed, RLNs must be scheduled for transport at specific POEs on specific aircraft or ships, at specific times and dates. The aircraft or ship assignment implies a specific POD.

Motivation

Current SM models do not efficiently assign the transportation modes for RLNs, employing either prestipulated modes or myopic methods. A complete and detailed review of such models is presented by McKinzie and Barnes.⁶ Three of these are the Deployment Network Tool Extended (DANTE)⁷, Strategic Transportation Quick Look (STQL)⁸ and Joint Flow and Analysis System for Transportation (JFAST) Link.⁹ As shown in this article, the results from these models can be *significantly* improved upon by the application of modern direct search.

Problem Statement

We assume the following information is specified.

- Aircraft and ship quantities, availability dates, and types at each starting location.
- Open ports (POE and POD) for transportation.

We assume the following information is given in TPFDD (Level 3) format: For each

- RLN: Origin, destination, RLD, ALD, EAD, LAD, RDD, size, priority, and whether contents are hazardous.
- Aircraft or ship: capacity, speed, range, type.
- Port: ship and aircraft capacities, fuel and refuel capacities, maximum aircraft on ground and berths, number of takeoffs and landings per day, and on- off- load capabilities.

Conversations with subject matter experts¹⁰ reveal that, from a command viewpoint, a RLN's *priority* is, de facto, its LAD. However, one RLN of 350 lbs arriving one day late is *not* equivalent to an RLN of 13 Stons arriving one day late. A simple yet representative method of calculating lateness is to multiply Stons by days late. In addition, the relatively low number of aircraft and their significantly higher cost per trip compared to ships must be considered. Hence, the consensus was that the objective function value for the SMMSP should be computed by adding: (1) the total number of ship trip legs, (2) ten times the number of aircraft legs, and (3) for each RLN, the LAD violation time in days multiplied by its Stons.

For example, ten aircraft trips, ten ship trips, and three RLNs of 50 Stons each arriving 3 days late would yield an objective function value of 560 units.

A Small SMMSP

Tables 1 through 6 present a schedule generated by JFAST for 17 RLNs that were extracted from a contingency deployment to Tunisia. All columns are self explanatory except for column *M* which indicates the item transport mode (X - item not moved, P - optional mode, S - sea mode, A - air mode).

Table 1's first RLN, 05AAL, is designated for air transport and weighs 882 Stons. (PAX are allocated one-fifth Ston per individual). Since strategic aircraft carry no more than 92 Stons, 05AAL requires at least ten aircraft. Strategic ships can haul at least 18,000 Stons, but require 2 or more weeks to travel from CONUS to Jerba-Zarzis, Tunisia (JEAH). 05AAL's LAD is day 100 and it can depart on day 0.

Table 2 lists the 11 PAX RLNs that must travel by air. (05BC needs no transport because it is at its destination. This type of superfluous content is not unusual in a typical TPFDD.) The remaining ten RLNs depart from six different POEs and arrive at three PODs. Given sufficient pressurized aircraft, Table 3 shows one possible valid on time schedule. Table 4 details the remaining 5 RLNs to be scheduled. (02CB's current OCONUS location (CWFA) is in Italy and need not be considered for strategic transport.)

Of the remaining five items, one is scheduled for air, three for sea, and 01AAC's mode is optional. However, since 01AAC's POE (ZBES) and POD (FTZH) are both sea ports, its mode is

POE : UHGN	departure day: 0	POD: JEAH	arrival day: 1	STon: 1744	Veh Req'd: 19
RLN: 0 is : 00KB	Unit		Stons: 1744		
POE : FTEV	departure day: 0	POD: FUQN	arrival day: 1	STon: 410	Veh Req'd: 5
RLN: 0 is : 05BB	Unit		Stons: 29		
RLN: 1 is : 05BD	Unit		Stons: 382		
POE : CYWF	departure day: 13	POD: JEAH	arrival day: 14	STon: 5690	Veh Req'd: 62
RLN: 0 is : 00BE	Unit		Stons: 3522		
RLN: 1 is : 05AAF	Unit		Stons: 1286		
RLN: 2 is : 05AAL	Unit		Stons: 882		
POE : LEXG	departure day: 15	POD: JEAH	arrival day: 16	STon: 182	Veh Req'd: 2
RLN: 0 is : 05BKB	Unit		Stons: 182		
departure day: 15	POD: MQNA	arrival day: 16	STon: 385	Veh Req'd: 5	
RLN: 0 is : 05BKD	Unit		Stons: 385		
POE : TMKH	departure day: 18	POD: JEAH	arrival day: 19	STon: 405	Veh Req'd: 5
RLN: 0 is : 00DDA	Unit		Stons: 210		
RLN: 1 is : 00JCC	Unit		Stons: 195		

Table 3. Passenger Schedule

RLN	Description	PAX	Bulk	Over	Out	Orig	RLD	POE	ALD	POD	EAD	LAD	M	Dest	RDD
00AJ	STINGER MISSILES	0	168	0	0	HCTL	0	QKJA	12	JEAH	12	25	A	JEAH	25
01AAC	CORPS FINANCE GROUP	0	80	160	0	HCTL	6	ZBES	18	FTZH	24	26	P	FTZH	26
00KCC	HHD AIR TRAFFIC CONTROL B	0	100	829	1480	HFTZ	0	LCMT	0	FTZH	0	9999	S	FTZH	9999
00GDC	AR CO AR BN ABN DIV/SEPBD	0	0	0	191	HCTL	0	ZBES	12	FTZH	12	22	S	FTZH	22
00FTC	FWD COMM CO ABN	0	341	108	0	HCTL	0	ZBES	18	FTZH	24	28	S	FTZH	28

Table 4. RLNs Currently Unscheduled

POE : QKJA

departure day: 12 POD: JEAH arrival day: 13 STon: 168 Veh Req'd: 3

RLN: 0 is : 00AJ Unit Stons: 168

Table 5. Air Cargo Schedule

POE : ZBES

departure day: 13 POD: FTZH arrival day: 27 STon: 191 Veh Req'd: 1

RLN: 0 is : 00GDC Unit Stons: 191

departure day: 25 POD: FTZH arrival day: 39 STon: 689 Veh Req'd: 1

RLN: 0 is : 00FTC Unit Stons: 449

RLN: 0 is : 01AAC Unit Stons: 240

POE : LCMT

departure day: 1 POD: FTZH arrival day: 15 STon: 2409 Veh: 1

RLN: 0 is : 00KCC Unit Stons: 2409

Table 6. Sea Schedule

changed to S. If the designated POE and POD could be modified, it is possible that 01AAC's mode could be changed to air. Tables 5 and 6 detail the remaining air and sea transport. The RLNs in Table 6 depart from ZBES (Wilmington, NC) and LCMT (Houston, TX) and all planned departures embody trivial loads that will arrive after their LAD.

This example uses only 17 RLNs. A typical TPFDD has over 4,000 RLNs. Since JFAST was used, no heuristic was employed to improve the solution either by (1) rearranging RLNs within their assigned POEs or PODs, (2) by moving RLNs to another POE or POD or (3) by exercising possible transport mode changes. As described below, utilizing such options can greatly improve the solution associated with any set of cargo.

Research Goals

The primary goals of the research documented here were to:

- Develop methods for producing a *suite* of excellent solutions to any instance of the SMMSP.
- Produce a model for the SMMSP that allows reusability of the model within the various SMMS models used by the Department of Defense (DoD).
- Conduct a comparison of our TS methods to an existing SM method.

Goal 1 was accomplished with an Adaptive Tabu Search (ATS) approach, ATS-SMMSP, where an adaptive neighborhood schema reallocated one or more RLNs from one transportation asset to another. Goal 2 was addressed implementing the model in JAVA. Finally, goal 3 was achieved by comparing the results of ATS-SMMSP to those of JFAST.

The remainder of this article consists of four sections. The second section recounts several relevant SM models, overviews pertinent associated TS topics and reviews associated military applications of TS. The third section presents a small example of a SMMSP and describes the ATS-SMMSP. The fourth section presents a comparison of results of the ATS-SMMSP and JFAST. The final section presents conclusions and proposes additional areas of investigation.

A Review of SM Literature and Associated TS Approaches

This section reviews available SM literature and the three aspects of TS most relevant to this research.

SM Models Overview

SMMSP literature is principally found in military publications and in unpublished information residing in the community of users and programmers of specific mobility models. SM models differ in sponsoring organizations, operating systems, ease of use, interoperability with other models, input and output interfaces, mode selection capability, level of detail, mission profile versatility, and computational efficiency. Where appropriate, these criteria will be addressed in the following sections. A detailed review of current and legacy models may be found in McKinzie and Barnes.¹¹

High Level SM Models with No Mode Selection

This class of *quick look* models is employed in early planning, uses only regional origin and destination designations, uses approximate travel distances, combines unit equipment and resupplies, allows only macroscopic decisions, and provides a broad understanding of required time frames for timely delivery of all items. These models provide an early assessment of planning feasibility and the need for a redesign of the plan.

Examples of such tools are the Deployment Network Tool Extended (DANTE),^{12, 13} JFAST-Link¹⁴ and the Strategic Transportation Quick Look (STQL).¹⁵

Level IV SM Models (With Mode Selection)

This class of models includes:

- The Global Deployment Analysis System (GDAS), which provides extensive capabilities for analysis but can require a *significant* amount of time and effort to tailor it to a specific model. GDAS performs a deterministic *simulation* to determine the actual arrival, departure, loading, unloading, and queuing events at each facility.
- JFAST, the model of choice for the detailed planning community. JFAST is High Level Architecture-compliant and includes a TPFDD editor.

- The Model for Intertheater Deployment By Air and Sea (MIDAS), where all input and output files must be viewed and edited as flat files. The intense complexity of the MIDAS model presents a significant roadblock for many planners who have little experience and education in modeling. MIDAS's mode selection first assigns all cargo (except nonair transportable materiel) to aircraft. If available aircraft cannot feasibly transport all RLNs, all RLNs that can meet their RDD when moved by ship (Ship-RDD RLNs) are identified and MIDAS begins to assign such Ship-RDD RLNs to ships. MIDAS can produce schedules with individual aircraft tail numbers and can track RLN Level 6 detail.
- The private proprietary, expensive Mobility Simulation Model (MobSim), is portable and easy to use, consisting of a simulation tool that models multiple modes of transportation. MobSim reports the *first* feasible solution found unless instructed to report a global optimal solution. If a global optimum is required, MobSim attempts to secure it through exhaustive search.¹⁶ Although a feasible solution can be reported in minutes, an excellent solution will usually not be found in an acceptable amount of time.

Tabu Search

In this section, aspects of TS particularly relevant to the SMMSP are discussed and an overview of historical TS applied to military combinatorial optimization problems is presented.

Classical applications of TS have focused primarily on the solution of combinatorial optimization problems.¹⁷ The numerous TS successes are attributable to several characteristics including TS's abilities to traverse infeasible solution space regions and to escape local optima.

TS guides the search by recording attributes of visited solutions and forbidding return to such solutions before *tabu tenure* iterations have occurred. TS repeatedly chooses the best non-tabu solution from a predefined neighborhood of solutions until a termination condition is met. While early TS implementations used a static constant tabu tenure, advanced tabu memory structures can dynamically determine the *tabu tenure* for a solution or class of solutions.^{18,19} TS can also be enhanced through the use of intensification and diversification strategies.^{20, 21}

ATS-SMMSP uses a simple dynamic memory structure that defines a minimal, maximal, and initial tabu tenure. While enforcing the tenure extremes, an improving move yields a tabu tenure increment and a nonimproving move yields a decrement to the tabu tenure.²² This simple enhancement to the TS memory structure can result in marked improvements in efficiency and effectiveness of a TS approach.

Battitti and Tecchiolli²³ introduced a more powerful dynamic TS memory structure, reactive TS (RTS). The number of repeated solution visitations is recorded. When solutions are repeated frequently, the tabu tenure is increased rapidly. The tabu tenure is quickly decreased when solutions are not frequently repeated. They also implemented a diversification *escape* technique that is used when "there is evidence that the system is in a complex attractor of the search space."²⁴ and Nanry and Barnes²⁵ developed advanced applications of RTS.

Related TS Applications

The TS implementations briefly discussed in this section were developed to solve complex military problems. These and the

application presented in this article were built under the aegis of an ongoing consortium consisting of representatives from The University of Texas, the Air Force Institute of Technology, the Air Mobility Command and the Air Force Office of Scientific Research. These models greatly improve upon previous approaches by providing near optimal solutions in remarkably small amounts of time.

The *Aerial Fleet Refueling Problem* (AFRP)²⁶ is concerned with inflight refueling of a fleet of Air Force aircraft. The associated TS approach addressed a multicriteria set of goals and dramatically reduced the time and resources required for solution. In a typical large scale deployment scenario, the TS AFRP methodology yielded an ensemble of excellent solutions in about 4 hours. Previous methods required a team of analysts months to obtain a workable solution.

The *Aerial Fleet Crew Scheduling Problem* (AFCSP)^{27,28} complements the TS AFRP model. The TS AFCSP model addresses the scheduling of the crews that operate associated AFRP aircraft and significantly improves the solutions found from current methods in remarkably short periods of time.

The *Theater Distribution Vehicle Routing and Scheduling Problem* (TDVRSP) model²⁹ uses an abstract algebraic view. Once the cargo or passenger arrives at the POD, each must be moved to the final destination. The TS TDVRSP model maintains total asset visibility and intransit visibility of vehicle assets and is a much more efficient and effective solution methodology than previous approaches. Although the US Air Force once deemed the TDVRSP too difficult for optimization, this new TS technique has shown that statement to be *incorrect*.

The ATS approach to the *Strategic Airlift Problem* (SAP)³⁰ produces detailed routing and scheduling of strategic airlift resources which are dramatically superior to the current approach embodied in Air Mobility Operations Simulator. This approach extends the dynamic neighborhood selection methodology first developed by Harwig.³¹

The SAP is a component of the SMMSP. ATS-SMMSP stipulates the mode of transport for each RLN and assigns RLNs to vehicles at a more macroscopic level than the SAP. The TS SAP model requires the prior stipulation of what items will be transported by air and focuses, in a more detailed manner, on solving the routing and scheduling of air movement. In addition to the SAP, the SMMSP solves the Strategic Sealift Problem at a macroscopic level.

TS and SM

The SMMSP is a large combinatorial optimization problem with partitioning, scheduling, and routing aspects. Partitioning occurs in the assignment of RLNs to a particular mode of transportation. Scheduling is inherent in the assignment of RLNs to particular POEs, PODs, and departure days. In addition to the RLNs being routed from their origin, POE, POD, and finally to their destination, the vehicles moving these RLNs are also scheduled and routed over multiple trips during the deployment operations. Each time the RLN reassignment causes a change in departure day or number of vehicles required for movement on a given day, the vehicles are rerouted.

Current models use greedy procedures to obtain feasible solutions to the problem. Classical optimization methods are incapable of providing timely solutions; thus, this problem is ideally suited for a TS approach. The next section details the ATS-SMMSP algorithm developed in this research.

The ATS-SMMSP Algorithm—Modeling and Methodology

A TPFDD stipulates all needed information for the transport of cargo for a given contingency and the solution of the SMMSP yields a redefinition of a TPFDD.

Two Representations of the SMMSP

There are two SMMSP solution representations using either vehicle routing or RLN routing. The vehicle routing representation groups the time stamps, paths, and RLNs by vehicle. The RLN routing representation groups the RLNs by POE, departure day, and POD. The small SMMSP example of Table 1 illustrated the RLN routing representation. Table 7 presents a vehicle routing solution representation of another small example which uses two wide-body planes (WBPs) and one B-747P to route the RLNs. Table 8 presents an equivalent RLN routing representation for the example of Table 7.

Both WBPs' maximum load is 59 Stons and the B-747P's maximum load is 93 Stons. All aircraft are available on day 0 at POE WWYK (Tinker Air Force Base, OK). WBP-1 performs five

trips. After flying to NRCH (Loring Air Force Base, Maine), WBP-1's first trip is on day 7 with one RLN of 2 Stons. After delivering cargo to AEQT (Algeciras [Gibraltar], Spain), it returns to PTFL (McGuire Air Force Base, NJ) and picks up 35 Stons on day 20 and unloads at AEQT on day 22. It then returns to PTFL, picks up 48 Stons on day 30 and delivers it to VRJT (Sigonella, Italy). Returning to NRCH, it picks up 6 Stons on day 34 and delivers it to AEQT. Finally WBP-1 returns to NRCH picking up 3 Stons on day 46 and delivering to AEQT. WBP-1's total routing was {Port (day, Ston)}: WWYK(0,0) – NRCH(7,2) – AEQT(9,0) – PTFL(20,35) – AEQT(22,0) – PTFL(28,48) – VRJT(30,0) – NRCH(34,6) – AEQT(36,0) – NRCH(46,3) – AEQT(48,0).

The second WBP performs a single trip with routing WWYK(0,0) – PTFL(35,14) – AEQT(37,0). The last aircraft, B-747P-1 performs three trips with a routing of WWYK(0,0) – PTFL(35,93) – AEQT(37,0) – NRCH(46,10) – UMXB(48,0) – NRCH(53,3) – AEQT(55,0).

This small example addresses only nine RLNs. Typical problems address thousands of RLNs and the inherent complexity of the SMMSP precludes the use of classical optimization methods. A heuristic approach that obtains an

excellent solution in a relatively short amount of time is superior to either a poor solution achieved more quickly or to a provably optimal solution that requires insupportable time and effort. A direct search approach, like ATS, can successfully manage the presence of the many time window constraints and still track each RLN and vehicle as a unique entity.

An ATS Approach to the SMMSP

The highly successful applications of ATS to complex military logistics problems reviewed in Section 2 led to the use of ATS for this research. While TS does not guarantee an optimal solution, a well constructed TS methodology uses aspects of the problem structure to achieve excellent solutions with supportable computational effort. The ATS approach described in this section monitors such things as late arriving RLNs, time window flexibility and the number and type of transport vehicles available to enhance the search process.

The DoD hierarchically delegates authority to several levels of command. Within SM planning, associated commands

Air Cargo: WBP-1

day: 0	Port: WWYK	Load: 0	Unused: 59
day: 7	Port: NRCH	Load: 2	Unused: 57
RLN: 0 is :	5HJAV	Unit	Stons: 2
day: 9	Port: AEQT	Load: 0	Unused: 59
day: 20	Port: PTFL	Load: 35	Unused: 24
RLN: 0 is :	6ACBP	Unit	Stons: 35
day: 22	Port: AEQT	Load: 0	Unused: 59
day: 28	Port: PTFL	Load: 48	Unused: 11
RLN: 0 is :	0FBB	Unit	Stons: 48
day: 30	Port: VRJT	Load: 0	Unused: 59
day: 34	Port: NRCH	Load: 6	Unused: 53
RLN: 0 is :	5HCAS	Unit	Stons: 6
day: 36	Port: AEQT	Load: 0	Unused: 59
day: 46	Port: NRCH	Load: 3	Unused: 56
RLN: 0 is :	5HCAJ	Unit	Stons: 3
day: 48	Port: AEQT	Load: 0	Unused: 59

Air Cargo: WBP-2

day: 0	Port: WWYK	Load: 0	Unused: 59
day: 35	Port: PTFL	Load: 14	Unused: 45
RLN: 0 is :	0EDB	Unit	Stons: 107
day: 37	Port: AEQT	Load: 0	Unused: 59

Air Cargo: B-747P-1

day: 0	Port: WWYK	Load: 0	Unused: 93
day: 35	Port: PTFL	Load: 93	Unused: 0
RLN: 0 is :	0EDB	Unit	Stons: 107
day: 37	Port: AEQT	Load: 0	Unused: 93
day: 46	Port: NRCH	Load: 10	Unused: 83
RLN: 0 is :	5WYH4	B Unit	Stons: 5
RLN: 1 is :	5WYH4	C Unit	Stons: 5
day: 48	Port: UMXB	Load: 0	Unused: 93
day: 53	Port: NRCH	Load: 3	Unused: 90
RLN: 0 is :	5HEBA	Unit	Stons: 3
day: 55	Port: AEQT	Load: 0	Unused: 93

Table 7. Example Vehicle Routing Solution Representation

coordinate priorities and interests and reach agreements regarding RLNs and transportation assets. Commanders specify RLN ports and modes and are *very* resistant to change. For this reason, the ATS-SMMSP performs three stages of analysis. Stage 1 solves the SMMSP preserving the commanders' port and mode assignments. Stage 2 preserves specified transport modes but allows RLN POE and POD changes. Stage 3 allows RLN port and transport mode changes. Stage 2 and 3 solutions may be used to demonstrate the *improved* solutions available for commanders willing to relax some of their preferences.

The ATS-SMMSP solution representation lists each RLN with its (POE/departure-day/POD) triplet. Since each POE (POD) is either an air or sea port, any RLN port assignment *defines* the mode of transport. Known transit times imply that any departure day stipulates the arrival day and directly allows accounting for any LAD violations. All ATS-SMMSP search neighborhoods allow and penalize delivery after the LAD, but strictly prohibit violations of RLD and EAD. RLN transport priority is dictated by the earliest LAD.

The software implementation of the ATS-SMMSP methodology is divided into three parts: (1) *Input* focuses on data validity, (2) *ATS* performs scheduling and assignment and (3) *Output* presents the new TPFDD generated by the ATS-SMMSP.

ATS-SMMSP Input

ATS-SMMSP requires six data files. The first three contain information associated with airplanes, ships and geographic locations. The airplane information includes the airplane type, maximum and minimum loads, speed, and size limitations. Due to the numerous ship configurations, only averages for ship types are available. For each ship type, the ship information also includes the speed, maximum and minimum draft, loading time and maximum load. The geographic location information is used for location verification and for time and distance calculations.

The remaining three contingency-specific files are the TPFDD, Vehicles Available, and Open Ports. The initial location, type, and available date of all vehicles are provided in the Vehicles Available file. TPFDD and Open Port files must be checked for validity and completeness. Some TPFDD errors and omissions can be easily corrected. For example, if a port indicated by a TPFDD is not an open port for a scenario, it is replaced with the closest open port in the port file. Another example would be when a POE-POD pair are incompatible mode types and require correction.

Scheduling and Assignment

As detailed by McKinzie,³² prior to search commencement, the validated TPFDD file is used to create an initial ATS-SMMSP solution. This is performed by having RLNs move precisely as stated in the TPFDD, departing their TPFDD-designated POEs on the designated available load dates. Vehicles are greedily

assigned to the triplets in order of earliest departure day, by first available vehicle. The initial solution is usually *not* good with many RLNs arriving late and many vehicles transporting trivial loads. This and other types of solution deficiencies are corrected by the ATS-SMMSP.

This greedy assignment is illustrated by the small example in Table 8 which, without loss of generality, considers only PAX. Two POEs are used—NRCH (Loring AFB, Maine) and PTFL (McGuire AFB, NJ). First, consider the RLNs at NRCH. On day 7, aircraft 5 departs with 5HJAV carrying a trivial load of two Stons. On day 34, aircraft 0 departs with 5HCAS (six Stons). On day 46, aircraft 8 transports three Stons to AEQT and aircraft 9 transports ten Stons to UMXB. Finally on day 53, aircraft 7 transports three Stons. Now, focusing on PTFL, aircraft 23 departs on day 20 with 35 Stons and aircraft 29 departs on day 28 with 48 Stons. On day 35, aircraft 24 and 10 transport 0EDB with a total of 107 Stons. Aircraft 24 is maximally loaded with 92 Stons and aircraft 10 transports the remaining 15 Stons. Each mission except PTFL mission 2 is far below their 50 percent trivial load weight.

This greedy assignment used nine aircraft trips for eight missions. The only temporally overlapping trips depart on day 46 and on days 34 and 35. The nine trips could have been accomplished using three unique aircraft. The cost of moving the RLNs would be the same and six aircraft would remain free for other uses such as providing earlier transport for RLNs that would arrive later than their LADs. Additional significant gains in efficiency could also be possible if the LADs would allow RLN aggregation onto fewer aircraft without increasing lateness.

ATS-SMMSP Search Stages

Stage 1 uses two phases to seek improvements without changing predefined ports or modes by considering moves in defined search neighborhoods. The best qualifying (non-tabu or aspiration satisfying) neighbor becomes the new incumbent solution. Phase I considers only *late RLNs* ordered by descending lateness penalty (days late times RLN Stons). Table 9 expands Table 8 providing ALD, EAD, and LAD detail. The three late RLNs are considered in the order 5WYH4 C, 5HCAJ, and 5HEBA.

POE : NRCH					
departure day:	7	POD: AEQT	arrival day:	8	STon: 2 1 Veh: #5
RLN: 0 is :	5HJAV	Unit	Stons:	2	
departure day:	34	POD: AEQT	arrival day:	35	STon: 6 1 Veh: #0
RLN: 0 is :	5HCAS	Unit	Stons:	6	
departure day:	46	POD: AEQT	arrival day:	47	STon: 3 1 Veh: #8
RLN: 0 is :	5HCAJ	Unit	Stons:	3	
departure day:	46	POD: UMXB	arrival day:	47	STon: 10 1 Veh: #9
RLN: 0 is :	5WYH4	Unit B	0	Stons: 5	
RLN: 1 is :	5WYH4	Unit C	0	Stons: 5	
departure day:	53	POD: AEQT	arrival day:	54	STon: 3 1 Veh: #7
RLN: 0 is :	5HEBA	Unit	Stons:	3	
POE : PTFL					
departure day:	20	POD: AEQT	arrival day:	21	STon: 35 1 Veh: #23
RLN: 0 is :	6ACBP	Unit	Stons:	35	
departure day:	28	POD: VRJT	arrival day:	29	STon: 48 1 Veh: #29
RLN: 0 is :	0FBB	Unit	Stons:	48	
departure day:	35	POD: AEQT	arrival day:	36	STon: 107 2 Veh: #24,10
RLN: 0 is :	0EDB	Unit	Stons:	107	

Table 8. Initial Solution for the Passenger Example

Phase I examines late RLN using a *port-pair* neighborhood. Since 5WYH4 C has the unique port-pair NRCH-UMXB, it has *no* moves available. 5HCAJ and 5HEBA have port pair NRCH-AEQT. Hence, 5HCAJ has three possible moves. Moving to NRCH-7-AEQT is rejected for ALD violation. Moving 5HCAJ to NRCH-34-AEQT yields an arrival 12 days earlier (a lateness

decrease of 36 Ston-days) and is the *best* current move. Moving to NRCH-53-AEQT adds seven more days delay and is discarded.

5HEBA is nine days late. Moving to NRCH-7-AEQT is discarded for ALD violation but moving to NRCH-34-AEQT yields a total lateness reduction of 37 Ston-days, the new *best* move. Moving to NRCH-46-AEQT yields a lesser reduction of 31 units and is discarded.

Following the complete neighborhood evaluation, the best move is executed. Phase I is applied until no moves exist. For our example, this yields the results of Table 10 with a lateness of 145 with seven aircraft used.

Phase II differs from Phase I only in the search neighborhood which does not require lateness and consists of the smaller of 10 percent of all RLNs or 100 RLNs. The RLNs are considered in ascending order by RLN Stons and alphabetically within equal Stons. For the current example, the list for Phase II is 5HJAV, 5HCAJ, 5HEBA, 5WYH4 B, 5WYH4 C, 5HCAS, 6ACBP, 0FBB, and 0EDB.

Phase II completes Stage 1 and yields the results in Table 11 with a lateness of 135 using six aircraft. Stage 1 reduced lateness by 93 units and three fewer aircraft are required. The best solution from Stage 1 is the initial solution for Stage 2 where pre-selected ports are not enforced. This is the first algorithm to allow improving port selections in an automated approach.

In Stage 2, logistical restrictions limit the distance to new replacement ports. Better security and transportation allow 700 miles in CONUS as opposed to 200 miles in OCONUS. As presented in the pseudocode of Figure 2, at each iteration, all RLNs are considered and the best allowable move is executed. The Stage 2 neighborhood is much larger than its Stage 1 counterpart because it considers all RLNs and relaxes the constraint that preserves port-pairs. The Stage 2 maximum time limit encompasses both Stage 2 and Stage 1.

```
POE : NRCH
departure day: 7   POD: AEQT   arrival day: 8   STon: 2   1 Veh: #5
  RLN: 0 is : 5HJAV   Unit           Stons: 2   ALD: 4   EAD: 6   LAD:40
departure day: 34  POD: AEQT   arrival day: 35  STon: 6   1 Veh: #0
  RLN: 0 is : 5HCAS   Unit           Stons: 6   ALD: 26  EAD: 32  LAD:50
departure day: 46  POD: AEQT   arrival day: 47  STon: 3   1 Veh: #8
  RLN: 0 is : 5HCAJ   Unit           Stons: 3   ALD: 10  EAD: 11  LAD:30
departure day: 46  POD: UMXB   arrival day: 47  STon: 10  1 Veh: #9
  RLN: 0 is : 5WYH4   Unit B 0       Stons: 5   ALD: 34  EAD: 36  LAD:50
  RLN: 1 is : 5WYH4   Unit C 0       Stons: 5   ALD: 20  EAD: 24  LAD:35
departure day: 53  POD: AEQT   arrival day: 54  STon: 3   1 Veh: #7
  RLN: 0 is : 5HEBA   Unit           Stons: 3   ALD: 30  EAD: 32  LAD:45

POE : PTFL
departure day: 20  POD: AEQT   arrival day: 21  STon: 35  1 Veh: #23
  RLN: 0 is : 6ACBP   Unit           Stons: 35  ALD: 20  EAD: 24  LAD:29
departure day: 28  POD: VRJT   arrival day: 29  STon: 48  1 Veh: #29
  RLN: 0 is : 0FBB    Unit           Stons: 48  ALD: 23  EAD: 26  LAD:34
departure day: 35  POD: AEQT   arrival day: 36  STon: 107  2 Veh: #24,10
  RLN: 0 is : 0EDB    Unit           Stons: 107 ALD: 29  EAD: 36  LAD:44
```

Table 9. Phase I Search Example (Reducing Lateness)

```
POE : NRCH
departure day: 7   POD: AEQT   arrival day: 8   STon: 2   1 Veh: #5
  RLN: 0 is : 5HJAV   Unit           Stons: 2   ALD: 4   EAD: 6   LAD:40
departure day: 34  POD: AEQT   arrival day: 35  STon: 12  1 Veh: #0
  RLN: 0 is : 5HCAS   Unit           Stons: 6   ALD: 26  EAD: 32  LAD:50
  RLN: 1 is : 5HCAJ   Unit           Stons: 3   ALD: 10  EAD: 11  LAD:30
  RLN: 2 is : 5HEBA   Unit           Stons: 3   ALD: 30  EAD: 32  LAD:45
departure day: 46  POD: UMXB   arrival day: 47  STon: 10  1 Veh: #9
  RLN: 0 is : 5WYH4   Unit B 0       Stons: 5   ALD: 34  EAD: 36  LAD:50
  RLN: 1 is : 5WYH4   Unit C 0       Stons: 5   ALD: 20  EAD: 24  LAD:35

POE : PTFL
departure day: 20  POD: AEQT   arrival day: 21  STon: 35  1 Veh: #23
  RLN: 0 is : 6ACBP   Unit           Stons: 35  ALD: 20  EAD: 24  LAD:29
departure day: 28  POD: VRJT   arrival day: 29  STon: 48  1 Veh: #29
  RLN: 0 is : 0FBB    Unit           Stons: 48  ALD: 23  EAD: 26  LAD:34
departure day: 35  POD: AEQT   arrival day: 36  STon: 107  2 Veh: #24,10
  RLN: 0 is : 0EDB    Unit           Stons: 107 ALD: 29  EAD: 36  LAD:44
```

Table 10. Example Phase I Results

```
POE : NRCH
departure day: 34  POD: AEQT   arrival day: 35  STon: 14  1 Veh: #0
  RLN: 0 is : 5HCAS   Unit           Stons: 6   ALD: 26  EAD: 32  LAD:50
  RLN: 1 is : 5HCAJ   Unit           Stons: 3   ALD: 10  EAD: 11  LAD:30
  RLN: 2 is : 5HEBA   Unit           Stons: 3   ALD: 30  EAD: 32  LAD:45
  RLN: 3 is : 5HJAV   Unit           Stons: 2   ALD: 4   EAD: 6   LAD:40
departure day: 46  POD: UMXB   arrival day: 47  STon: 10  1 Veh: #9
  RLN: 1 is : 5WYH4   Unit B 0       Stons: 5   ALD: 34  EAD: 36  LAD:50
  RLN: 2 is : 5WYH4   Unit C 0       Stons: 5   ALD: 20  EAD: 24  LAD:35

POE : PTFL
departure day: 20  POD: AEQT   arrival day: 21  STon: 35  1 Veh: #23
  RLN: 0 is : 6ACBP   Unit           Stons: 35  ALD: 20  EAD: 24  LAD:29
departure day: 28  POD: VRJT   arrival day: 29  STon: 48  1 Veh: #29
  RLN: 0 is : 0FBB    Unit           Stons: 48  ALD: 23  EAD: 26  LAD:34
departure day: 35  POD: AEQT   arrival day: 36  STon: 107  2 Veh: #24,10
  RLN: 0 is : 0EDB    Unit           Stons: 107 ALD: 29  EAD: 36  LAD:44
```

Table 11. Results of the Phase II Search Process

Continuing with the example of Tables 9 through 12, POE NRCH is close enough to PTFL and to several other POEs for RLNs to move to a different triplet using any of these POEs. Similarly, because they are within 200 miles of one another, POD UMXB (Rota, Spain) and POD AEQT can be used interchangeably. All RLNs except 0FBB at PTFL-28-VRJT are current candidates for port change.

Table 12 presents the results for Stage 2. NRCH-7-AEQT, NRCH-46-AEQT, NRCH-53-AEQT and PTFL-28-VRJT are unchanged. 5HCAJ moved to PTFL-20-AEQT (changing its POE) and arrived on time at a cost savings of 15. 5WYH4 C moved to NRCH-34-AEQT (changing its POD) for a cost savings of 60 and 5WYH4 B moved to PTFL-35-

AEQT reducing aircraft usage by one. At this point, no RLN is late and the total penalty of 50 units is due to the five required aircraft

In Stage 3, transportation modes may be altered. Our small PAX example restricted all RLNs to air transport. Only cargo RLNs may change modes, which *implies* a port change for our mode-specific ports. Figure 3 presents a high-level pseudo code for Stage 3. The maximum time-stopping criteria includes the time consumed by all three stages.

Other ATS-SMMSP Considerations

The ATS-SMMSP tabu memory structure is straightforward. An RLN may not be moved if it has been moved within the last *tabu tenure* iterations. The aspiration criterion allows tabu RLNs to move only if that would produce the best solution found so far in the search. Each RLN in the current search neighborhood is evaluated and the best *allowable* move yields the new incumbent solution. The tabu tenure varies in each stage. The initial tabu tenure is one-tenth the size of the candidate list of RLNs. The tabu tenure adaptively changes by decrementing with an improving move and incrementing with a nonimproving move. This adaptive procedure aids in intensifying and diversifying the search relative to a myopic measure of search history.³³

McKinzie³⁴ presents a detailed discussion of the

stopping criteria used in the ATS-SMMSP algorithm. These stopping criteria were based on total iterations, iterations since the best solution, iterations since an improved solution, and the total computation time.

ATS-SMMSP Outputs

Two of the three outputs from the ATS-SMMSP algorithm, the vehicle routing solution representation and the RLN triplet solution representation, have been presented above. The final type of output is a Joint Planning and Execution System³⁵ B-8 TPFDD which contains the information required by JFAST, the model used for discussing comparative results in the next section.

POE : NRCH									
departure day:	34	POD: AEQT	arrival day:	35	STon:	16	1 Veh:	#0	
RLN: 0 is :	5HCAS	Unit	Stons:	6	ALD:	26	EAD:	32	LAD:50
RLN: 1 is :	5HEBA	Unit	Stons:	3	ALD:	30	EAD:	32	LAD:45
RLN: 2 is :	5HJAV	Unit	Stons:	2	ALD:	4	EAD:	6	LAD:40
RLN: 3 is :	5WYH4	Unit C 0	Stons:	5	ALD:	20	EAD:	24	LAD:35
POE : PTFL									
departure day:	20	POD: AEQT	arrival day:	21	STon:	38	1 Veh:	#23	
RLN: 0 is :	6ACBP	Unit	Stons:	35	ALD:	20	EAD:	24	LAD:29
RLN: 1 is :	5HCAJ	Unit	Stons:	3	ALD:	10	EAD:	11	LAD:30
departure day:	28	POD: VRJT	arrival day:	29	STon:	53	1 Veh:	#29	
RLN: 0 is :	0FBB	Unit	Stons:	48	ALD:	23	EAD:	26	LAD:34
departure day:	35	POD: AEQT	arrival day:	36	STon:	112	2 Veh:	#24,10	
RLN: 0 is :	0EDB	Unit	Stons:	107	ALD:	29	EAD:	36	LAD:44
RLN: 1 is :	5WYH4	Unit B 0	Stons:	5	ALD:	34	EAD:	36	LAD:50

Table 12. Results of Stage 2 Search Process

```

While Stage 2 time limit not exceeded
{
  Until a Stage 2 iteration count termination criterion is satisfied
  {
    For each transport mode- air or sea
    {
      For each RLNs of this mode
      {
        For each neighborhood solution
        {
          evaluate objective function and determine tabu and aspiration status
          store best Stage 2 neighbor found
        }
      }
    }
    Move to best allowable Stage 2 solution found
  }
  Perform Stage 1 search
  Save best solution found
}

```

Figure 2. Within Mode Search Pseudo Code

```

While Stage 3 time limit not reached
{
  Until a Stage 3 iteration count termination criterion is satisfied
  {
    For each neighbor cargo RLN triplet within distance limitations
    {
      evaluate objective function and determine tabu and aspiration status
      save best found Stage 3 solution
    }
    Move to best Stage 3 solution found
  }
  Execute Stage 2 (and Stage 1)
}

```

Figure 3. Pseudo Code for Stage 3

ATS-SMMSP Comparative Computational Results

This section reports the ATS-SMMSP results for the widely used, typical large single foreign theater deployment described by the unclassified *Tunisia TPFDD* provided by US Transportation Command (USTRANSCOM) J5. USTRANSCOM also supplied the air and sea files. The Center for Army Analysis provided the geographic location information used for location verification and for time and distance calculations.

These results are then compared to the results obtained by JFAST using the identical inputs used for ATS-SMMSP.

ATS-SMMSP Results

The Tunisia TPFDD contains 21,356 usable lines of data (6,666 RLNs) and has 144 cargo aircraft and 55 passenger aircraft allocated. The cargo aircraft originate at POE WWYK and the passenger aircraft originate at Logan International Airport, Boston, Massachusetts. Transit time from any CONUS to any OCONUS port was modeled as 3 days (load, flight, unload). There were 344 ships available within 15 different ship types initially located at different OCONUS locations around the world. Their average capacity was 25,000 Stons and transit time from CONUS to OCONUS was modeled as 14 days.

The ATS-SMMSP TPFDD validation module found 3,040 RLNs with errors and required 4 minutes to repair 2,585 RLN errors and discard 455 unrepairable RLNs. This resulted in 6,211 available RLNs. This *unprecedented* automated repair procedure increased the available RLNs by a *remarkable* 40 percent! All current DoD models simply discard RLNs in need of repair.

The initial greedy solution and the dramatically improved ATS-SMMSP Stage 1 solution are summarized in Table 13. Proceeding to Stage 2, each Stage 2 execution, terminated by an iteration count condition, was followed by a Stage 1 execution. Once the maximum time stopping criteria was reached, Stage 2 terminated. Stages 2 and 1 were executed ten times prior to termination. Table 13 shows that all metrics were improved, with a 10 percent decrease in late RLNs and a more than 20 percent decrease in total days late. The reductions achieved are *not possible* in current DoD SM models.

After each execution of Stage 3, Stage 2 is executed. (Stage 1 is executed within Stage 2). Stage 3 was executed six times before the maximum allowed time was reached. The best solution was found after a total computation time of 15 hours and 44 minutes. As shown in Table 13, improvements were made to all metrics except passenger aircraft usage. The increase in available cargo aircraft used brought about significant additional reductions in four other metrics. This procedure is the *first* demonstration of a mode replacement heuristic within SM Modeling. The

improvements in reduction of lateness demonstrate the important capabilities of this method.

Figure 4 plots the objective function values against time for the Stage 3 search. The six executions of Stage 3 in this figure are evident by the groupings of starting values. The large point indicated by the oval on the graph indicates when the best objective function value was first found at Stage 3 execution 4. This value was saved as the best solution. Two more unique solutions with the same objective function value were found during Stage 3 execution 4.

JFAST Tunisia

To obtain comparable results, the identical TPFDDs from each ATS-SMMSP stage were input to JFAST. All scenario parameters were as stipulated in the ATS-SMMSP implementation. The input setup for JFAST is discussed in detail in McKinzie.³⁶ JFAST executes relatively quickly with the longest run taking less than 12 minutes. Since the time differences in all runs were small, additional analysis will not include run time comparisons.

Table 14 shows the total late arrivals (in 1,000 Stons) for the JFAST and ATS-SMMSP runs. The *dramatic* improvements in all three stages, reductions of at least 99.5 percent, emphasize the significant superiority of the ATS-SMMSP methodology. The number of late passenger Stons *are* higher in ATS-SMMSP. However with each passenger equating to 400 lbs, the maximal number of late passengers was no more than 70, a very acceptable value.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Section 4 presented the ATS-SMMSP results for a TPFDD widely used in DoD. It then compared those results to the results from JFAST. This section discusses the unique contributions of this research and suggests directions for future research.

The contributions documented here include unprecedented developments and implementations in four arenas: (1) automated repair of TPFDDs, (2) application of advanced TS techniques to the SMMSP, (3) strategic modifications of command prespecified TPFDD port allocations, and (4) strategic modifications of command prespecified TPFDD transport mode specifications.

There are several additional areas that could be investigated. Here are three that deserve immediate attention.

- The research reported here was performed under the auspices of The University of Texas at Austin which required that no classified materials be used. For this reason, the ATS-SMMSP applied to only one instance of a TPFDD, the only unclassified TPFDD available. To establish the general applicability of

		Stage 1		Stage 2		Stage 3	
	Initial	Results	% Reduced	Results	% Reduced	Results	% Reduced
Obj Fn Value	3,402,252	618,289	81.83	400,879	35.16	324,234	19.12
Cargo Aircraft	1,070	804	24.86	794	1.24	1,020	(-28.46)
Passenger Aircraft	1,338	985	26.38	969	1.62	969	0.00
Ships	306	224	26.80	223	0.45	209	6.28
Number Late RLN	2,158	1,354	37.26	1,218	10.04	1,143	6.16
Total Days Late	57,408	11,414	80.12	8,944	21.64	8,625	3.57

Table 13. Vehicle Usage and Lateness

the ATS-SMMSP, it should be applied to a wide range of TPFDDs. McKinzie³⁷ provides an initial look at that research direction where several parametric variants of the Tunisia TPFDD are considered.

- The current ATS-SMMSP does not begin with a good starting solution. An improved starting solution methodology would enhance the overall performance of the ATS-SMMSP.
- This current ATS-SMMSP used rudimentary techniques for vehicle assignment and route scheduling. Improved methods should be developed.

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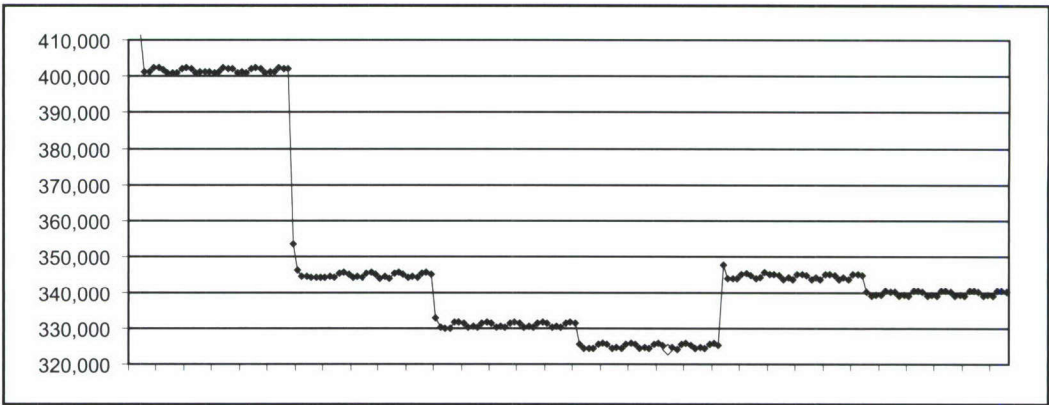



Figure 4. Stage 3 Objective Function Plot

	Cargo Stons		Passenger Stons		Total Stons	
	JFAST	SMMSP	JFAST	SMMSP	JFAST	SMMSP
Stage 1	11,894	47	6	14	11,900	61
Stage 2	11,894	35	6	13	11,900	48
Stage 3	11,827	17	6	13	11,833	30

Table 14. Passenger and Cargo Ston (in 1,000 Stons) Arrival Violations

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Until foundational issues are resolved and solutions fully tested and vetted, DoD will continue to treat the symptoms of our Joint logistics ills. If it does so, the same logistical failures and missed opportunities to properly support our combat forces which have plagued Joint operations throughout our recent history will be observed again in the next conflict.

logistics history

Baffled by DAFL: Directive Authority History for Logistics

Most observers of Operation Enduring Freedom and Operation Iraqi Freedom agree that the conduct of major combat operations was successful. However, when experts analyze the logistical performance of United States Central Command and other components of the US armed forces, many critiques arise. Numerous anecdotes of less-than-satisfactory support given to combat units can be found, from the lack of spare parts experienced by ground forces driving into the heart of Iraq to the inability to more effectively coordinate intratheater distribution, that clearly indicate room for improvement. The fact that some of these same criticisms were made in the aftermath of Operation Desert Storm in 1991 suggests that, while we may have learned from our mistakes in the past, we have

not made the necessary changes in our logistics operations to avoid repeating them.

In “Baffled by DAFL: Directive Authority History for Logistics” the author explores this topic first by addressing the various sources of guidance—doctrinal, directive, Joint, and Service—that stipulate how Joint logistics is to be conducted. Then, three main areas of Joint logistics operations are discussed—visibility, distribution, and communications and information technology capabilities. For these, a brief historical analysis of their effectiveness in Operations Desert Storm, Enduring Freedom, and Iraqi Freedom is provided. Lastly, conclusions for each aspect are drawn and recommendations offered for improving shortcomings in the future.

directive authority history for logistics

Baffled by DAFL

Article Acronyms

AOR - Area Of Responsibility
C2 - Command and Control
CDDOC - USCENTCOM
Deployment and Distribution
Operation Center
CINC - Commander in Chief
CJTF - Coalition Joint Task
Force
COCOM - Combatant
Commander
CUL - Common-User Logistics
CULT - Common-User Land
Transportation
DAFL - Directive Authority for
Logistics
DoD - Department of Defense
DIRMOBFOR - Director of
Mobility Forces
GAO - Government
Accountability Office (GAO)
IT - Information Technology
JLC - Joint Logistics Command
JP - Joint Publication
JMC - Joint Movement Center
JPO - Joint Petroleum Office
JCMEB - Joint Civil-Military
Engineering Board
JFSCC - Joint Force Support
Component Commander
JTF - Joint Task Force
JTLM - Joint Theater Logistics
Management
LRC - Logistics Readiness
Center
LOC - Logistics Operations
Center
ODS - Operation Desert Storm
OEF - Operation Enduring
Freedom
OIF - Operation Iraqi Freedom
OPCON - Operational Control

Introduction

The first essential condition for an army to be able to stand the strain of battle is an adequate stock of weapons, petrol, and ammunition. In fact, the battle is fought and decided by the quartermasters before the shooting begins.

—Field Marshal Erwin Rommel

Most observers of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) agree that the conduct of major combat operations was successful. However, when experts analyze the logistical performance of United States Central Command (USCENTCOM) and other components of the US armed forces, many critiques arise.¹ Numerous anecdotes of less-than-satisfactory support given to combat units can be found, from the lack of spare parts experienced by ground forces driving into the heart of Iraq² to the inability to more effectively coordinate intratheater distribution.³ These criticisms clearly indicate there is room for improvement. The fact that some of these same criticisms were made in the aftermath of Operation Desert Storm (ODS) in 1991 suggests that, while we may have learned from our mistakes in the past, we have not effected the necessary changes in our logistics operations to avoid repeating them.

Recent discussions have centered on a perceived inability of the regional combatant commander (COCOM) to effectively carry out directive authority for logistics (DAFL). Critics charge that, among many things, the lack of a *single point of contact* for Joint logistics theater management (JTLM) caused the inadequacies. Many of those who point to this shortfall advocate the creation of a theater logistics component commander to fulfill this role. Others disagree with this assessment and highlight problems with force flow, information capability, and other factors as key deficiencies. The key to any effort to learn from mistakes, however, is ensuring that the right problems are identified. If we do not identify the true root causes, we may correctly solve the symptoms of the problem, but further exacerbate the underlying ineffective condition. More importantly, we may witness yet another operation in which logistics fails to live up to the warfighters' expectations.

This article explores this topic first by addressing the various sources of guidance—doctrinal, directive, Joint, and Service—that stipulate how Joint logistics is to be conducted. Then, three main areas of Joint logistics operations are discussed: visibility, distribution, and communications and information technology (IT) capabilities. For these issues, a brief historical analysis of their effectiveness in ODS, OEF, and OIF is provided. Lastly, conclusions for each aspect will be drawn and recommendations offered for improving these shortcomings in the future.

Until foundational issues are resolved and solutions fully tested and vetted, DoD will continue to treat the symptoms of our Joint logistics ills. If it does so, the same logistical failures and missed opportunities to properly support our combat forces which have plagued Joint operations throughout our recent history will be observed again in the next conflict.

The Problem

If the transportation system will support, or can be developed in time to support, the forces necessary to carry out the operations plan, the rest of the logistics can usually be brought into line within a reasonable time.

—General Carter B. Magruder, USA

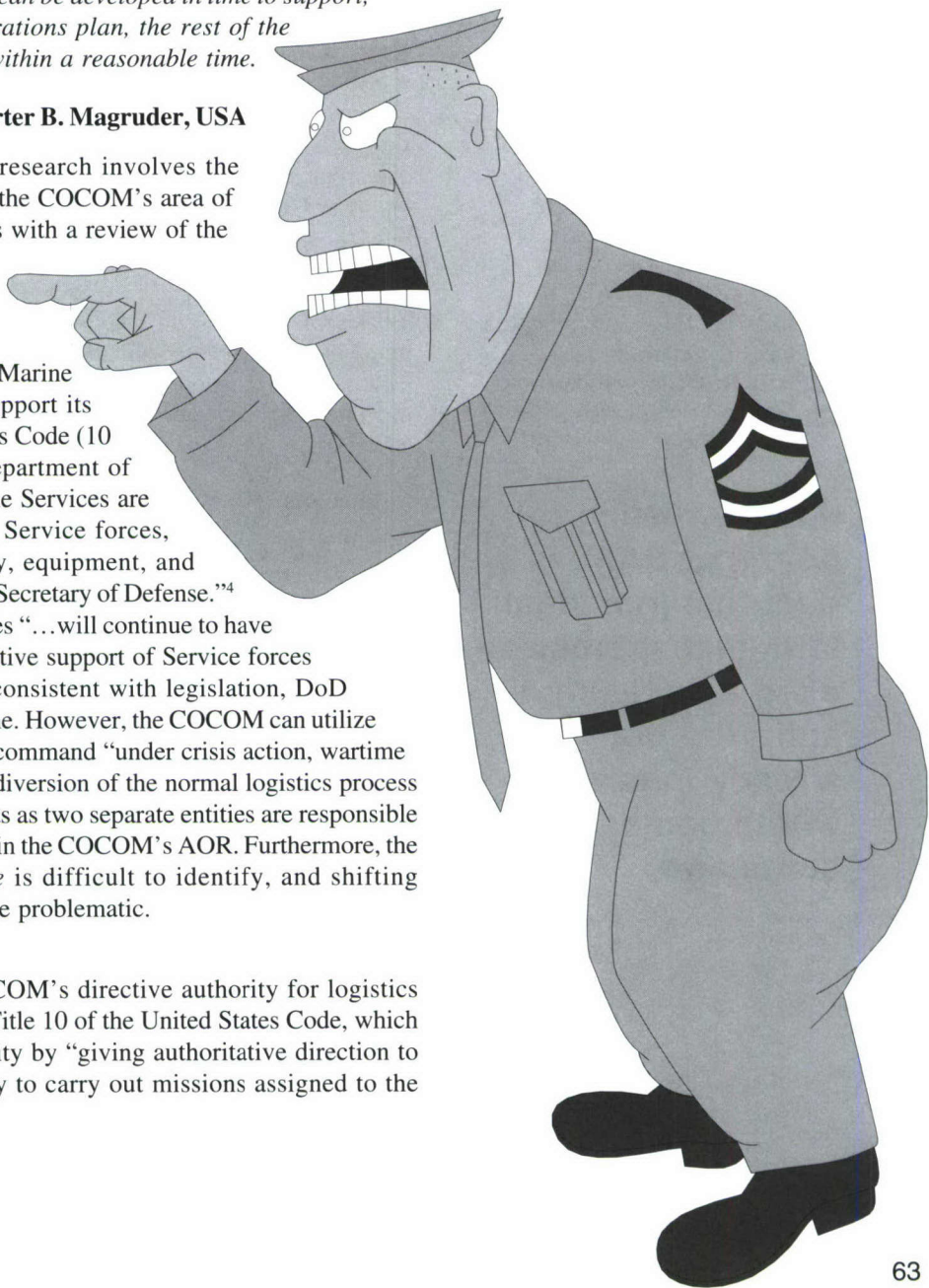
The main area of dialogue impacting this research involves the division of responsibility for logistics within the COCOM's area of responsibility (AOR). This discussion begins with a review of the responsibilities each of the Services bears with respect to Joint logistics.

The Services and Title 10

First, each of the Services—Air Force, Army, Marine Corps, and Navy—bear the obligation to support its forces worldwide. Title 10 of the United States Code (10 USC) and subordinate guidance such as Department of Defense (DoD) Directive 5100.1 state that the Services are required to "...provide logistic support for Service forces, including procurement, distribution, supply, equipment, and maintenance, unless otherwise directed by the Secretary of Defense."⁴ Joint Publication (JP) 4-0 explains that Services "...will continue to have responsibility for the logistics and administrative support of Service forces assigned or attached to Joint commands"⁵ consistent with legislation, DoD directives, and other guidance during peacetime. However, the COCOM can utilize all of the Services' resources assigned to the command "under crisis action, wartime conditions, or where critical situations make diversion of the normal logistics process necessary."⁶ Therefore, a natural tension exists as two separate entities are responsible for the logistics support of the forces assigned in the COCOM's AOR. Furthermore, the boundary between *peacetime* and *wartime* is difficult to identify, and shifting responsibilities once it has been identified are problematic.

The Combatant Commander

The next issue for consideration is the COCOM's directive authority for logistics (DAFL). The source of this authority is also Title 10 of the United States Code, which states that the COCOM executes this authority by "giving authoritative direction to subordinate commands and forces necessary to carry out missions assigned to the



Baffled by DAFL: Directive Authority History for Logistics



Article Acronyms (continued)

SJTFHQ - Standing Joint
Task Force Headquarters
SM - Single Manager
TACON - Tactical Control
TAV - Total-Asset Visibility
TDC - Theater Distribution
Center
USCENTCOM - United States
Central Command
USTRANSCOM - United
States Transportation
Command

It is interesting to note that DAFL is a doctrinal (not legal) term that at times is used as a distinct authority not already inherent within combatant command.

command, including authoritative direction over all aspects of military operations, Joint training, and logistics.”⁷ From this legislation, several Joint publications further detail this authority so that it can be performed by the COCOM (see Figure 1).

JP 0-2 states that combatant command “...cannot be delegated or transferred,”⁹ and JP 4-07 says that this authority pertains to “...assigned forces in specific Joint operations.”¹⁰

It is interesting to note that DAFL is a doctrinal (not legal) term that at times is used as a distinct authority not already inherent within combatant command. For example, DAFL is defined in JP 1-02 as

Combatant commander authority to issue directives to subordinate commanders, including peacetime measures, necessary to ensure the effective execution of approved operation plans. Essential measures include the optimized use or reallocation of available resources and prevention or elimination of redundant facilities and overlapping functions among the Service component commands.¹¹

The lack of reference to the previously determined *combatant command* authority seems to imply that DAFL is somehow a different power. JP 0-2 clouds the topic further because it is contradictory, stating, “Commanders of combatant commands exercise directive authority for logistics and may delegate directive authority for a common support capability.”¹² This implies that DAFL is somehow separate from the combatant command that cannot be delegated. Other Joint publications (namely 4-0 and 4-07) further describe a separate DAFL and its applicability to Joint theater logistics operations, but end up diluting or confusing the COCOM’s authority.¹³ As with all of the other functions for which the COCOM is responsible, there is a staff directorate that manages the logistics issues on his behalf and under his authority.

The Logistics Staff

The COCOM’s logistics directorate (J4) is charged with “the formulation of logistic plans and with the coordination and supervision of supply, maintenance, repair, evacuation, transportation, engineering, salvage, procurement, health services, mortuary affairs, security assistance, host-nation support, and related logistic activities.”¹⁴ The J4 staff performs the following key functions.

- Monitors current and evolving theater logistic capabilities
- Coordinates logistics support with upcoming operations
- Advises the Commander in Chief (CINC) on the supportability of proposed operations or courses of action
- Acts as the CINC’s agent and advocate to nontheater logistic organizations¹⁵

As with all other staff directorates, the J4 takes the actions necessary to ensure unity of effort and accomplishment of the command’s assigned mission.¹⁶ “The degree of authority to act in the name of and for the commander is a matter to be specifically prescribed by the commander.”¹⁷

While the COCOM is ultimately responsible to effectively apply logistics toward his operations, how it is achieved is somewhat muddled. For example, JP 4-07 says that “The combatant commander’s directive authority does not discontinue Service responsibility for logistic support even if it is being executed by another Service or agency.”¹⁸ What is clear, however, is the desire for effective command and control (C2) of theater logistics to successfully support combat operations. In the end, how does the execution of DAFL impact the logistics support of combat forces? An analysis of theater logistics in ODS, OEF, and OIF is appropriate to answer this question.

Discussion

Before any plans can be made to provide an army, logistics must be provided first. History has changed a lot, but logistics has been the crux of every one of

these changes; the nail that was missing which lead to the loss of country lead to a lot of those decisions.

—Major General Hugh Knerr, USAAF

The first aspect of theater logistics to discuss is the organization of the headquarters staff and subordinate units. The J4 staff, which manages the overall logistics operation in the AOR, is typically organized as shown in Figure 2.

Logistics Readiness Center

The logistics readiness center (LRC), when established, normally “manages the combatant commander’s directive authority over logistics and provides the coordination required to resolve logistics issues and problems.”¹⁹ The LRC may include the following boards or centers:

- Joint movement center (JMC)
- Joint petroleum office (JPO) or subarea petroleum office
- Joint civil-military engineering board (JCMEB)
- Joint facilities utilization board
- CINC logistic procurement support board
- Theater patient movement requirements center
- Joint blood program office
- Joint mortuary affairs office
- Joint medical surveillance team
- Joint materiel priorities and allocation board
- Joint transportation board²⁰

The COCOM also has the option to utilize these or other organizations to manage logistics when an LRC is not utilized.

Joint Theater Logistics Management

While the COCOM is ultimately responsible for the theater logistics operation, Joint doctrine offers a variety of options with regard to the logistics organizational structure used to attain Joint theater logistics management (JTLM).

JTLM integrates the logistic capabilities of the forces intheater to fulfill the common user and cross-Service support mission. When applied to the other challenges and desired operational capabilities of focused logistics, JTLM

facilitates support to the warfighter while achieving economies and reducing the logistic footprint. JTLM optimizes resources by synchronizing all logistic support efforts intheater. The objective is to provide rapid, timely delivery of forces, materiel, and sustainment to the combatant commander. JTLM provides to the combatant commander the ability to synchronize, prioritize, direct, integrate, and coordinate common user and cross-Service logistic functions necessary to accomplish the Joint theater mission.²¹

The primary decision the COCOM must make is how to align responsibilities for providing logistics support to subordinate units in the theater. The first choice is to leave the duty of supporting subordinate units with each Service, while the responsibility for common-user logistics (CUL), or the support of items or services used by more than one Service, is limited to

Combatant Command—Command Authority (Unique to Combatant Commander)

- Budget, planning, and programming input
- Assignment of subordinate commanders
- Relations with DoD agencies
- Convene courts-martial
- Directive authority for logistics

Figure 1. Combatant Command⁸

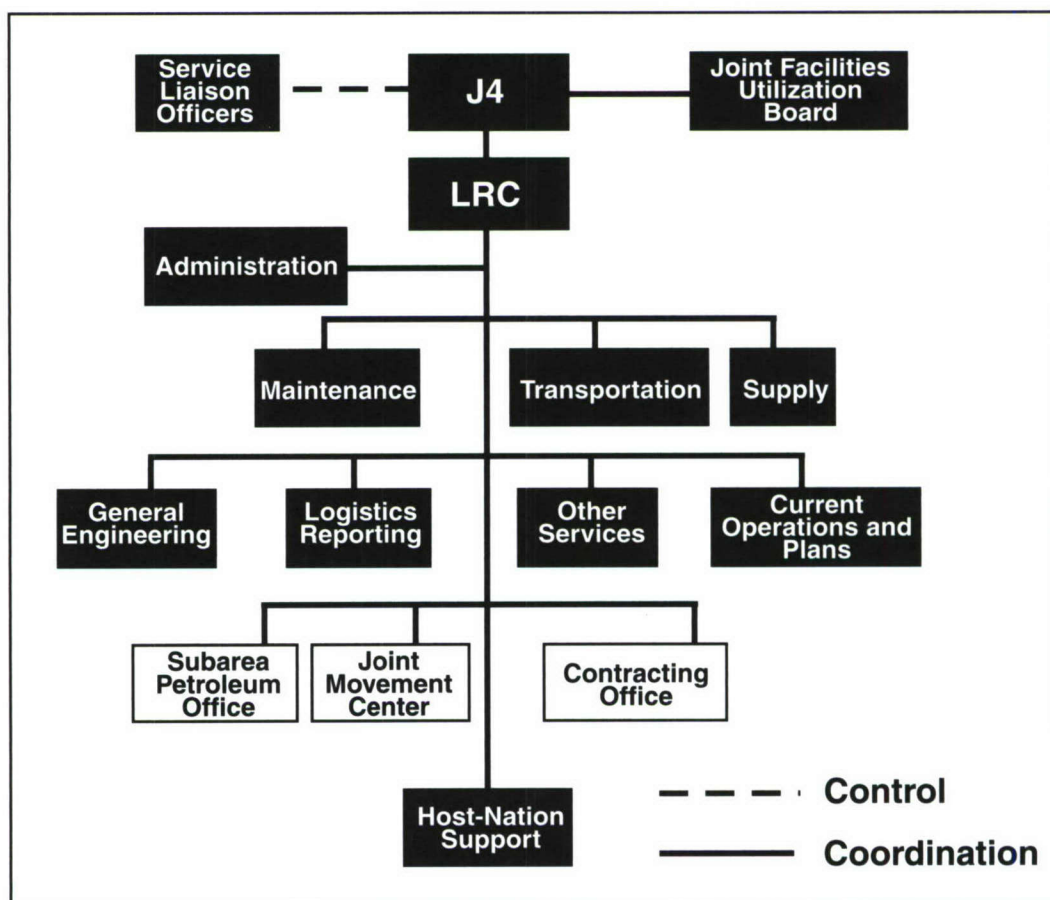


Figure 2. Typical J4 Organization with Logistics Readiness Center



In OEF, the deployment and employment of US forces was much more rapid than had been previously seen. The era of expeditionary warfare was upon us and each of the Services faced a *come as you are* situation.

preexisting agreements between the Services or coordinated by the COCOM's J4.²² Some advantages and disadvantages of this construct are as follows.

- Advantages of single-Service logistic support:
 - Does not require new command relationships
 - Allows each Service component to retain control of its own logistic assets
 - Does not require major adjustments to standard operating procedures
- Disadvantages of single-Service logistic support:
 - May require significantly more strategic lift requirements to properly execute
 - May increase operation costs
 - May increase deployment time
 - Will increase logistic footprint in theater
 - May require the use of J4 lead boards and centers to manage specific CUL functions²³

With the structure shown in Figure 3, the COCOM's J4 would manage the assignment of CUL responsibilities and cross-leveling (reassigning resources from one Service to another), while the determination of logistic priorities for assigned forces remains with each respective Service.²⁵

Another option available to the COCOM is to assign a Service or other DoD organization to be the lead agency for CUL support. In this scenario (shown in Figure 4), the COCOM will normally assign the Service that is the most dominant user or the Service most capable of managing the particular commodity or service this responsibility.²⁶ Also, the use of J4 boards and centers would only be used to "...coordinate or resolve issues above and beyond the capability of the lead Service or agency."²⁷ Some of the advantages and disadvantages of assigning a lead Service or agency include:

- Advantages of lead Service or agency option:
 - Reduces logistic redundancies
 - May significantly reduce the overall logistic footprint in theater
 - May reduce strategic lift requirements and deployment time
 - May significantly reduce overall cost
 - Allows each Service component to retain control of its own logistic organizations (without OPCON or TACON option)²⁸
 - Requires very little Joint staff, board, or center involvement to properly execute
- Disadvantages of lead Service or agency option:
 - May be less responsive than dedicated Service support
 - Requires new support relationships and adjustments to standard operating procedures
 - Requires new C2 relationships (if OPCON or TACON option is utilized)²⁹

Lastly, Joint doctrine also describes situations in which the COCOM may mix features of the two previous options. The spectrum of alternatives for the COCOM's single point of contact for logistical issues includes:

- Using a Service organization as its nucleus; for instance the Army Theater Support Command organizational concept
- Augmenting the J4
- Delegating to a Joint task force (JTF) commander
- Establishing a stand-alone logistic agency
- Expanding the logistics readiness center³⁰

JTLM in Previous Operations

The difficulties in establishing the theater logistics organization in ODS are well documented by Lieutenant General (Ret) Gus Pagonis in his book, *Moving Mountains: Lessons in Leadership and Logistics from the Gulf War*. He described a series of

improvisational decisions that led to his being chosen as the lead logistician in the AOR.

Almost as soon as we arrived in Saudi Arabia, Generals Schwarzkopf and Yeosock came to the shared conclusion that the only way they could operate successfully in the theater would be to establish a single point of contact for all logistical needs. I was it—the Deputy Commanding General for Logistics. Responsibility for fuel, water, food, vehicles, ammunition, all classes of supply (except equipment repair parts) for the Marines, Air Force, and the Army, as well as items common to all the Services (T-shirts, socks, and such), was entirely mine.³¹

Then, Pagonis had to pick from among deploying personnel as they entered the theater to become his staff in the Logistics Operations Center (LOC). As more forces arrived, the LOC eventually grew into a more robust organization that included “clusters of transportation experts on one side of the room, fuel people on the other, and nodes of food procurement specialists, airport, and port operations people.”³³ Eventually, the 22^d Support Command, with Pagonis at the helm, was established to direct the theater logistics operation. In the end, General Schwarzkopf chose to use a lead Service organization, an Army theater support command, to execute theater management of CUL.

In OEF, the deployment and employment of US forces was much more rapid than had been previously seen. The era of expeditionary warfare was upon us, and each of the Services faced a *come as you are* situation. Therefore, the initial logistics C2 rested with each of the Services’ forces in the Afghanistan AOR, and COCOM-level issues were handled back at USCENTCOM headquarters at MacDill AFB in Tampa, Florida.³⁴ A LOC was established under the auspices of the USCENTCOM/J4 to coordinate CUL and obtain materiel and services that the individual Services could not. In addition, a number of Joint boards and centers were utilized in the AOR to orchestrate support for in-country forces. For example, the Joint

Movement Center (JMC) took on the responsibility to coordinate the use of transportation resources available in Afghanistan. This function was placed under the direction of the Combined Forces Air Component Commander, located at the Combined Air Operations Center at Prince Sultan Air Base, Saudi Arabia, rather than under the Combined Forces Land Component Commander or a subordinate Army unit. Because the movement and use of organic land transportation assets was not viable, airlift became the main mode used for most cargo or personnel transport requirements at the outset of combat operations. There was a small movement control center that controlled a limited number of military trucks for Coalition Joint Task Force 180 (CJTF-180), the in-country headquarters for OEF.³⁵

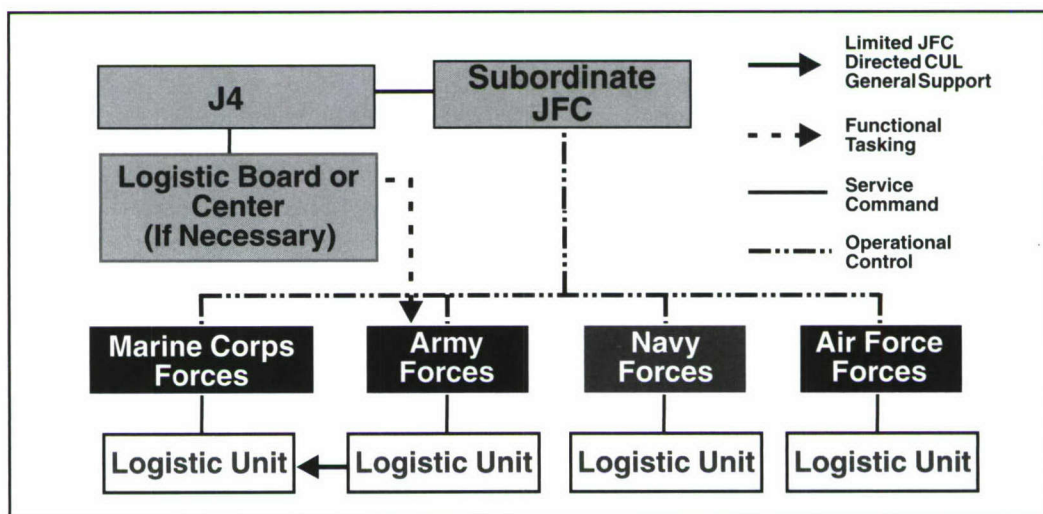


Figure 3. Single-Service Logistic Command and Control and Management Option²⁴

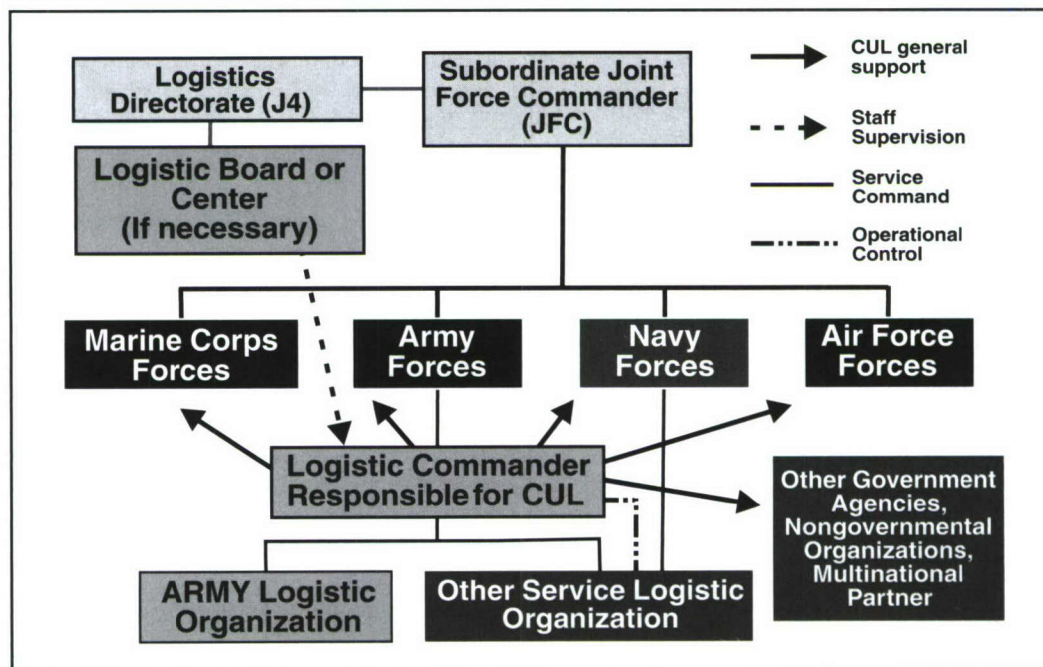


Figure 4. Lead Service Common-User Logistics Command and Control and Management Option³²

Baffled by DAFL: Directive Authority History for Logistics



The main criticism found in this research was the cumbersome process by which Service components must staff issues for resolution at the COCOM level. If there was a logistics requirement that could not be met by a Service or lead agent, the requesting unit had to coordinate the request through the Service component commander for a decision by the COCOM.

As more forces, namely Army personnel, flowed into the country, many of the functions managed back in Tampa moved forward and were assigned to the Joint Logistics Command (JLC) of CJTF-180 in Afghanistan. Over time, the JLC assumed more CUL functions and now operates as the single manager for in-country logistics for CJTF-76 (the successor to CJTF-180).

The operational logistics structure was not much different in OIF. Most of the logistics operation was controlled from USCENTCOM headquarters until late in 2002. At that point, a large number of personnel from the J4 staff moved forward to the AOR. The USCENTCOM/J4 staff operated the various Joint boards and centers, such as the LRC, JPO, and JCMEB. In the meantime, the Services controlled their respective logistics functions and CUL responsibilities. In fact, the Marine Corps created the Marine Logistics Command to control all Marine logistics operations in the Iraqi AOR, mainly the offloading and movement of combat equipment from cargo ships to their units in the field.³⁶ A clear example of the less-than-optimal arrangement of logistics responsibilities in OIF involves the JMC.

The JMC is “responsible for coordinating the employment of all modes of theater transportation (including that which is provided by allies, coalition partners, or the host nation) to support the theater concept of operations at the operational level with the JTF JMC or component movement center.”³⁷ It is the coordinator for all cargo and passenger movement into, through, and out of the theater and serves as the COCOM’s “focal point for strategic movements and should oversee the execution of theater transportation priorities.”³⁸ It is noted that the JMC did not fulfill this role in OIF.

In USCENTCOM, although there is a Joint Movement Center (JMC), the majority of distribution management is a component activity. At the highest level of the command, that [sic] appears not to have been the intention to execute a fully-functioning JMC. Processes used by the components were component-specific, not integrated into a single theater architecture. There were no common logistics procedures, shared communications, or joint control.³⁹

Furthermore, given its limited capabilities, the JMC focused mainly on intratheater air movements by C-130s with the occasional C-17. Although there was some coverage of intratheater sealift by the Army’s theater support vessel, logistics support vessels, and landing craft utility ships, the JMC did not attempt to manage the surface truck movements, delegating this function to the 377th TSC, which further delegated the responsibility to an Army movement control battalion. The lack of Joint visibility and management of common user ground transportation assets limited the Joint access to these platforms, which became primarily an Army-centric transportation fleet. Had the JMC followed doctrinal examples for the establishment of such a body, the common user ground transportation assets may have been more accessible to all of the Services and components.⁴⁰

The last critique of the JMC worth noting here is the disunity of effort experienced in OIF because

...the Director of Mobility Forces (DIRMOBFOR), the operator of the [airlift] schedule, was not colocated [sic] with the JMC at Camp Arifjan, but was based at Al Udeid AB in Qatar. The DIRMOBFOR would also add cargo to the existing airlift schedule [created by the JMC at Camp Arifjan]. There is little evidence that the JMC attempted to exercise comprehensive directive authority. In a complex AOR, it is essential that a fully functioning JMC be established and operated as a truly Joint command with developed processes and tools. This did not occur in OIF and this dispersion of command across components led to dilution of control.⁴¹

So while it appears that doctrine describes an integrated and effective JMC, it was not properly established or employed in OIF.

Major Issues in Recent Operations

Both OEF and OIF experienced a combination of logistics organizational options, with the use of Service-focused, lead Service, and COCOM-level units and capabilities. While there were numerous examples of logistics shortfalls in these operations, those

that can be attributed exclusively to doctrinal disparities are few. The main criticism found in this research was the cumbersome process by which Service components must staff issues for resolution at the Cocom level. If there was a logistics requirement that could not be met by a Service or lead agent, the requesting unit had to coordinate the request through the Service component commander for a decision by the Cocom. By the time the issue was reviewed by the appropriate J4 staff office or agency and forwarded for decision, the matter was often overcome by events. In that time, the requesting unit had either moved on to another course of action or fulfilled its need by another means.⁴² This was not a universal observation, since the Air Force seemed to be satisfied with the support they received from the Cocom under the organizational structure used in OEF and OIF.⁴³ However, the pace of combat will only grow faster, so perhaps a C2 structure that can support combat more quickly is needed. In fact, with the increased visibility and information and communications capabilities available through a logistics common operating picture,⁴⁴ the Cocom's LRC may actually predict logistics shortfalls and proactively engage to resolve those issues before a Service needs to react.

The second main area of analysis is the conduct of theater distribution, arguably the most important Joint logistics capability during war. The geographic Cocom is responsible for maintaining an effective distribution network and exercising visibility and positive control of personnel, materiel, and services in the AOR. To do this, the J4 manages the overall theater distribution operation by utilizing a series of boards, centers, and committees to prioritize and accomplish the management tasks.⁴⁵ The Service components also play a large role in theater distribution, as they provide the units that conduct the day-to-day tasks.

Each of the Services is assigned to perform various segments of the distribution process. These roles, known as executive agent or single manager (SM) tasks, are determined by Title 10, DoD directives, OPLANs, or other instructions. An example of an SM charge is the responsibility of the Department of the Army to provide common-user land transportation (CULT) including rail, in overseas areas, through the Commander, Army Forces (COMARFOR).⁴⁶ Therefore, the COMARFOR Director of Logistics (G4) establishes the procedures and determines the requirements to execute this responsibility. Coincidentally, the CULT mission in both ODS and OIF had shortcomings and, thus, has been discussed frequently in literature.

During ODS, the Army Central Command was responsible for providing food, water, bulk fuel, ground munitions, port operations, inland cargo transportation, and construction support for all US forces in the AOR.⁴⁷ The CULT function was inadequate for some time, however. Movement requirements outpaced the ground transportation capability throughout the operation, leading some to comment that, had ODS lasted longer, "maneuver forces would have outrun their fuel and other support."⁴⁸ One of the main reasons documented for this shortfall was the decision by USCENCOM to flow more combat forces and fewer logistics resources at the start of ODS. "The decision to sequence the deployment of the Service support units later in the deployment

flow severely affected the ability of the Army to provide the common-user requirements for the other Services. In some cases, even those logistics forces that did arrive were unable to meet all requirements, and USCENCOM had to rely on host-nation support to make up the shortages."⁴⁹ This situation had a significant ripple effect on theater logistics, especially at the sprawling ports bringing in huge amounts of materiel.

While the ports were important to the flow of personnel and materiel, the limited initial ability to move troops and equipment away from the ports to their preliminary combat positions became a weak link in the logistics chain. Inadequate numbers of US organic trucks, especially those with good off-road capability, and a limited main supply route network became severe challenges that had to be overcome.⁵⁰

This happened, despite the Army eventually deploying 72 percent of its truck companies to support 25 percent of its combat divisions.⁵¹ This problem was well documented after ODS, so one would think that DoD would take appropriate actions to ensure this did not happen again.

Unfortunately, some of these same problems were also witnessed in OIF. According to the US Government Accountability Office (GAO),

DoD did not have a sufficient distribution capability in the theater to effectively manage and transport the large amount of supplies and equipment deployed during OIF. For example, the distribution of supplies to forward units was delayed because adequate transportation assets, such as cargo trucks and materiel handling equipment, were not available within the theater of operations.⁵²

In addition,

The 377th Theater Support Command, responsible for logistics support in Kuwait, needed 930 light to medium trucks but had only 515 trucks on hand when combat began, creating a strain on materiel movement. Available transportation assets could not meet the Marine Corps' and the 3^d Infantry Division's capacity requirements. High-priority items such as food did not always move as intended. Contractors responsible for moving meals ready-to-eat from ports to the theater distribution center at times had only 50 of the 80 trucks needed. At one time 1.4 million meals ready-to-eat were stored at a port in theater, awaiting transport to customers.⁵³

Why did this happen? Once again "DoD did not time the mobilization and deployment of cargo truck units so that the system could be fully prepared to meet anticipated demands from the first day of operations."⁵⁴

DoD's priority was for combat forces to move into the theater first. A study suggested that distribution assets were either deleted from the deployment plan or shifted back in the deployment timeline. As a result, logistics personnel could not effectively support the increasing numbers of combat troops moving into theater. A shortage of support personnel in theater prior to and during the arrival of combat forces was reported, and those who arrived were often untrained or not skilled in the duties they were asked to perform. The shortage resulted in delays in the processing (receipt, sorting, and forwarding) of supplies and backlogs. Contractors performing distribution functions had become overwhelmed and a Joint contractor-military organization quickly evolved. As two divisions entered the theater, the need for a theater distribution center (TDC) became apparent and an area in the desert was designated as a storage and cross-dock area.⁵⁵

Baffled by DAFL: Directive Authority History for Logistics



There are three capabilities that enable effective theater distribution and represent the essence of the COCOM's directive authority: visibility, theater infrastructure, and command.

This lack of support capability again had enormous negative consequences for the combat forces in theater.

The establishment of the TDC only 2 weeks before crossing the line of departure meant that basic processes for support were not functioning, even while in Kuwait. Various units of the 3^d ID [Infantry Division] supplied personnel to the TDC to assist operations, but the Division Support Command also routed high priority parts via FedEx to deliberately avoid the TDC. The Air Force stationed a liaison officer at the TDC to divert cargo to Al Jabbar AB, the jumping-off point from their supply convoys. The Marines went straight to the air and seaports to redirect cargo to the Marine Logistics Command at Camp Fox, their version of the TDC. Immediately, all Services began to operate independently.⁵⁶

With respect to theater land distribution, "the failure to effectively apply lessons learned from Desert Shield, Desert Storm, and other military operations may have contributed to the logistics support problems encountered during OIF."⁵⁷

The last area of the logistics operation to be analyzed is the communications and information technology (IT) capability used by logistics forces. DoD has long recognized the importance of improving logistics IT in the 21st century. In fact, a stated goal is to attain information fusion which will provide "a secure, intranet environment allowing DoD users to access shared data and applications, regardless of location, supported by a robust information infrastructure"⁵⁸ This will create, "near real-time command and control of the logistics pipeline, one fused picture of combat support to the warfighter, and a closed link between command and control, and combat support during critical execution of an operation."⁵⁹ Therefore, any discussion on DAFL and how it is executed must include the information systems that enable C2 of logistics in a COCOM's theater. Unfortunately, this seems to be an area in need of significant improvement.

ODS occurred from 1990 to 1991 at the dawn of the modern computer age. It is understandable that IT was unable to provide capabilities such as total-asset visibility (TAV) that are expected today. These types of shortcomings in ODS are well documented. In fact, the phrase *iron mountain* is synonymous with DoD logistics in the first Gulf War. "During Operations Desert Shield and Desert Storm, asset visibility in the US wholesale system generally was adequate. However, visibility of assets while in transit and in theater was poor. This lack of visibility resulted in considerable confusion and reordering (sometimes multiple reordering) of the same items by field units concerned about existing or projected shortages of crucial items."⁶⁰ In essence, the forces lost their trust in the logistics system. These *iron mountains* also came about because the ports, both sea and air, could not definitively know what assets were arriving from the US, so they were ill-equipped to handle the sheer volume of materials flowing in. The items were then delayed while waiting to be processed, further exacerbating the problem. This problem was not limited to US forces, as the British Royal Army also noted that "one of our greatest failings in the Gulf was our inability to track assets and this is even more critical for the support of future operations."⁶¹

There were also difficulties with the communications capabilities of tactical units that made their sustainment even more tenuous.

The distance of the supply routes created communications problems within the logistical system because Army officials had difficulty communicating using their equipment, which was designed for much shorter ranges. Military doctrine called for units to be equipped for operating up to 90 miles from main supply bases. However, the Army supported military and logistics bases over 600 miles from its main supply bases.⁶²

Therefore, it was difficult for units in the field to input their requisitions for more supplies or equipment and to find out when they would arrive. This also motivated units to overstate their requirements when they actually could input their requests.

This type of behavior results in other subsequent negative consequences for the entire AOR. It further taxes an already limited lift capability that now has to move assets that are not actually needed. In addition, it makes C2 at the COCOM level that much more difficult because it forces the J4 staff and its subordinate boards and centers to play *catch up* and resolve the increased number of bottlenecks that occur. Staff

personnel, or the personnel at the ports, may choose to allocate lift resources to move unnecessary assets ahead of others, then not have the lift required to move more important items.

Unlike combat operators who were deluged with information, logisticians thirsted for it. Without timely and accurate requisition status, up-to-date unit location information, or sufficient ship, aircraft, and container manifest visibility, logisticians could not optimally support battlefield operations.⁶³

The 10-year period between ODS and OIF saw a revolution in IT and communications capabilities, but many of the same criticisms were voiced in analyses of the second Iraqi war.

The situation found in Iraq was best described by the GAO when it said, “during Operation Iraqi Freedom, commanders at the senior levels were not able to prioritize their needs and make decisions in the early stages of the distribution process because they did not know what was being shipped to them. The result was an overburdened and overtasked transportation and distribution system.”⁶⁴ The picture was not much better for distribution within the theater either.

The lack of intransit visibility over supplies impeded distribution. Because of incomplete radio frequency identification tags on incoming shipments, logistics personnel had to spend time opening and sorting the shipments, significantly increasing processing time. According to US Central Command, about 1,500 small arms protective inserts plates for body armor were lost and 17 containers of meals ready-to-eat were left at a supply base in Iraq for over a week because no one at the base knew they were there. Marine Corps officials became frustrated with their inability to see supplies moving towards them and lost trust and confidence in the logistics system and processes. Logistics systems used to order, track, and account for supplies were not well integrated and could not provide the essential information to effectively manage theater distribution.⁶⁵

By and large, “the inability to ... reliably, rapidly, and consistently communicate and satisfy logistics requirements limited the effectiveness of established processes during OIF.”⁶⁶

So how does this all relate to the analysis of DAFL execution in OEF and OIF? There has been much debate recently over the root causes of the logistical inefficiencies in these operations. Comments such as, “the limited evidence of the exercise of clear directive authority for logistics during OIF is consistent with and a logical consequence of the limitations found in the logistics chain”⁶⁷ and “in the case of OIF (DAFL) was not effectively employed”⁶⁸ provide the impetus for this discussion. In the course of examining this topic, some organizations recommended the creation of a single logistics commander in a COCOM’s theater to alleviate the difficulties. The real problem lies in separating the symptoms of the problem from the actual deficiency-hampering theater logistics.

Key Enabling Capabilities

There are three capabilities that enable effective theater distribution and represent the essence of the COCOM’s directive authority.

- **Visibility.** The ability to monitor the pipeline and obtain positive indicators that the distribution pipeline is responsive to customer needs.

- **Theater Infrastructure.** A system’s infrastructure dictates the capacity of a distribution system and distribution pipeline flow.
- **Command, Control, and Communication.** The application of control is required to implement the authority of the distribution manager as the focal point of logistic distribution-related functions.⁶⁹

Analyses of DoD’s performance in recent operations (ODS, OEF, and OIF) indicate that these capabilities were deficient. In OIF,

Lacking tools, process, and structure, the operational control over logistics devolved to the supporting units. Though doctrine empowers the COCOM to exercise directive authority, existing logistics capabilities limit the COCOM’s ability to exercise this power. Instead of residing with the COCOM, directive authority for logistics becomes dispersed. This lack of comprehensive focus and control meant that units and battalions were improvising and building ad hoc support systems to ensure their own wellness.⁷⁰

OIF was not without its triumphs as innovative thinking and cooperation led to the creation of the USCENTCOM Deployment and Distribution Operation Center (CDDOC). A C2 cell assigned to the USCENTCOM/J4 and comprised of personnel from USCENTCOM, United States Transportation Command (USTRANSCOM), and the Defense Logistics Agency (DLA), the CDDOC was designed to “link strategic deployment and distribution processes to operational and tactical functions in support of the warfighter, thereby improving end-to-end distribution within USCENTCOM’s area of responsibility.”⁷¹ In order to accomplish this mission, this group was given the following tasks.

- Confirm USCENTCOM deployment and distribution priorities
- Validate and direct Combined Force Air Component Commander intratheater airlift support to components and combined Joint task forces
- Monitor and direct the Coalition Forces Land Component Commander intratheater surface distribution support to components and combined Joint task forces
- Adjudicate identified USCENTCOM distribution and intratheater shortfalls
- Coordinate for additional USTRANSCOM support and materiel
- Set the conditions for effective theater retrograde⁷²

The CDDOC, termed by some to be a *JMC on steroids*,⁷³ offered “enhanced ITV [intransit visibility], reach back and decisionmaking authority, logistics experts within the reach of the warfighter, and actions in force flow and sustainment, all of which assisted the theater operational commanders in the accomplishment of their missions.”⁷⁴ It is clear that the Joint deployment and distribution operations center (based on the CDDOC) being implemented by each of the unified COCOMs is a step in the right direction, fusing the right capabilities into a “single point of contact for consolidation and dissemination of



While the available literature does not negate the JFSCC concept as a viable option available to a COCOM, adding another layer of bureaucracy to the Joint theater logistics organization is unlikely to produce improvements unless other problems are resolved first. In fact, the JFSCC concept may result in a loss of flexibility and control by Service components.

deployment and distribution information” that “optimizes information flow between multiple organizations, including coalition, agencies, nongovernmental organizations and other private entities.”⁷⁵ Thus, it addresses and helps to resolve the key constraining factor: the lack of communications and IT to enable visibility of the entire range of theater logistics.

Perhaps the next evolution of this concept is to make it a permanent fixture within the J4 staff of each COCOM so the transition of the unit to contingency operations is not delayed waiting for augmenting personnel to arrive. Another possibility would be to embed the JDDOC function in the new Standing Joint Task Force Headquarters (SJTFHQ) concept. US Joint Forces Command developed the SJTFHQ to provide “each COCOM with an informed and in-place command and control capability, intended to mitigate the challenges encountered as a result of the *ad hoc* nature of Joint task force headquarters formed in the past.”⁷⁶ Because the SJTFHQ is assembled and maintained prior to force employment, it provides the COCOM with a significant improvement to command and control.⁷⁷

A dedicated logistics organization responsive to the needs and direction of the JFC should be manned full time by highly trained and professional logisticians who actively participate from the beginning in all Joint operational planning evolutions involving the theater. This organization should be given the opportunity to build internal synergy and external relationships by working closely with the other staff elements and the JFC in deliberate planning and supporting Joint exercises prior to the beginning of a conflict. Finally, this organization must be given the clear responsibility for performing all theater logistics command and control actions in support of a particular operation.⁷⁸

A Joint Theater Logistics Command?

The advocates for a Joint force support component commander (JFSCC) or similar Joint theater logistics command point to the need for such a “single point of contact” to direct the logistics processes with comments like, “responsibilities for common support lack synchronization and are often in competition with one another and with multinational and interdepartmental agencies,” and “no single entity has been given the responsibility for providing the overall command and control.”⁷⁹ However, doctrine states that there are, in fact, designated points of contact that coordinate virtually every aspect of CUL through the J4’s LRC and various boards and centers. In fact, Joint doctrine states that “the LRC is the nucleus of all Joint logistic operations and the nerve center for the supported combatant commander in providing staff direction over Service component logistic systems and requirements.”⁸⁰ It appears that the JDDOC, as the successor for the JMC function, can finally fulfill the role needed by the COCOM.

Because of the Services’ Title 10 responsibilities, CUL is the only facet of theater logistics that the COCOM is expected to plan to control. As situations arise, the COCOM retains the ability to direct actions to ensure the success of the logistics operation. Therefore, the problems do not seem to arise because the proper organizational structure does not exist. Theater logistics is most affected by the factors described previously, namely a lack of visibility, inadequate distribution infrastructure, and communications limitations.

Lack of logistics communication is cited as one of the most pervasive weaknesses in OIF. In an austere theater, the necessary logistics communications infrastructure was not available, and the COCOM did not have the capability to deploy one in support of a rapidly moving combat force.⁸¹

Other contributing causes, including pushing more combat forces earlier in the deployment and delaying combat support resources, continue to exacerbate the problem and hamper efforts to control theater logistics. Therefore, DoD is unlikely to find more effective outcomes by applying a different organizational construct without resolving these problems.

A major reorganization of logistics command and control, when the evidence suggests that logistics command and control is not a problem, will not necessarily produce more efficient organizations. Increased efficiency should be obtained by reengineering and streamlining current processes.⁸²

Conclusions

Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.

—Guilio Douhet

Accounts of the logistics efforts in OEF and OIF show that, while combat forces were adequately supported, there remains much room for improvement. Most of the literature points out that although the theater commander always had the authority to control logistics, he never had the capability to perform that function—ad-hoc command and control and improvisation were the norm.⁸³ Among the many shortcomings that made supporting the fight more difficult were “insufficient planning, lack of transportation resources, challenging logistics lines, limited logistics communications capability, and disjointed processes,” and “in the end, warfighters simply lost faith in the logistician’s ability to get them what they needed when they needed it on the battlefield.”⁸⁴

The History Lesson

This situation, which seems to occur in every military operation undertaken by US armed forces, occurs for many reasons, including a lack of visibility of the entire logistics chain, an inadequate distribution infrastructure, and an unreliable communications capability. While the available literature does not negate the JFSCC concept as a viable option available to a COCOM, adding another layer of bureaucracy to the Joint theater logistics organization is unlikely to produce improvements unless these other problems are resolved first. In fact, the JFSCC concept may result in “a loss of flexibility and control by Service components, increased Service manpower costs if [it] fails to eliminate duplication of effort, and a perceived layering of logistics authority.”⁸⁵

In OIF, essential theater logistics processes, organization, and technology were ad hoc creations in response to the exigencies of the conflict. Organizational resources for logistics at the Joint command level were limited; theater logistics command, control, communication, and computer systems were disjointed and often ineffectual; and logistics execution devolved to the component commands. While the COCOM retains the responsibility for theater logistics, he has not been provided with necessary capabilities.⁸⁶

However, visibility is a tool to achieve specific outcomes in support of the following objectives.

- Reliably deliver the required item to the right location in the correct quantity at the time required from the most appropriate source
- Make available tools and information for decisionmakers to exercise effects-based management of the logistics network
- Manage end-to-end capacities and available assets across the end-to-end chain to best support warfighter requirements
- Promote the ability of the supported COCOM to effectively exercise directive authority over logistics⁸⁷

Recommendations

Because of these assessments, and others, DoD should:

- Focus efforts and resources on improving communications and IT capabilities to finally allow the COCOMs and their logistics staffs the visibility needed to effectively control Joint theater logistics operations
- Investigate the efficacy of further enhancing the JDDOC concept by placing it within the SJTFHQ
- Analyze the effects of these root problems prior to directing or further codifying symptomatic corrections such as the JFSCC construct

Until these foundational issues are resolved and solutions fully tested and vetted, DoD will continue to treat the symptoms of our Joint logistics ills. If it does so, the same logistical failures and missed opportunities to properly support our combat forces which have plagued Joint operations throughout our recent history will be observed again in the next conflict.

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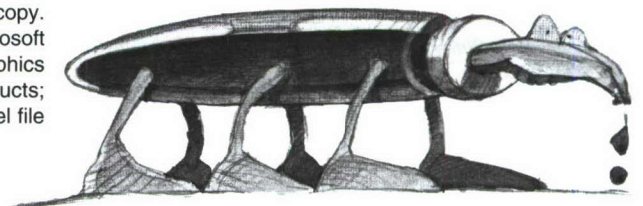
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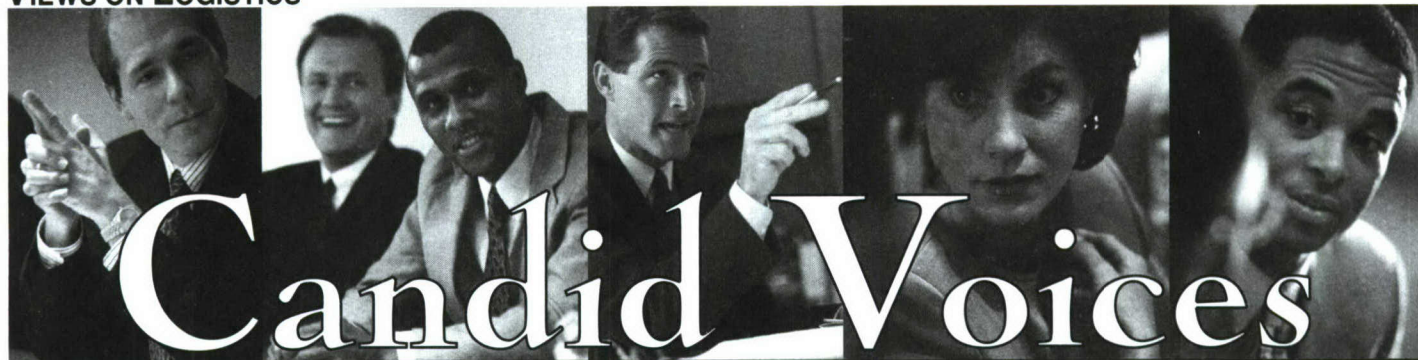
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The USAF Tech Data Dilemma—How Much Tech Data to Buy and When

Mike Farmer, AFIT Acquisition Logistics Course Director

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Buying tech data for new systems has a few land mines to watch for, but it does not have to be the *Nightmare on Elm Street* it all too often becomes. The nightmare usually starts with a very high price tag, causing a dilemma for program managers (PM). The PMs must make tough choices between meeting short-term acquisition budgets and schedules or providing for best value choices for the life cycle of the system. Years down the road, the nightmare unfolds when the readiness of aging weapon systems depends upon future program managers finding even more money to buy the data. At that point, the data has become essential, but the PMs simply cannot afford it.

Over the years, this issue has been explored by various government experts and key recommendations have been discussed. For example, a recent Government Accountability Office report recommended that PMs must "...emphasize the importance of having rights to the technical data needed to support the management of all logistics contracts." In describing an industry best practice, they found that, "every company visited told us they acquired the technical data necessary to support the equipment," whether they intended to support it in house or not. These companies described the data as, "essential to their own management and oversight functions."

Not only is it a best practice to acquire the data, Air Force PMs have been directed to do so "when needed." A 2003 Joint leadership memo (SAF/IL and AQ policy letters) calls data an essential corporate asset to support our systems and says it must be made available to those who need it.

So how do PMs avoid the nightmare? What actions can PMs take to comply with this guidance? This article explores the tech data dilemma and offers a concise recommendation to navigate the technical data land mines without disaster.

How Do PMs Get Into This Dilemma?

Many examples *litter the road* of recent procurements where a previous program manager decided not to buy the data or put any provisions in place to buy it later. A newly assigned PM comes along, charged with taking the program to the next level or with making a change in the operating and support strategy, and quickly realizes the desired objective cannot be achieved without the tech data that was not bought previously. "No

problem," says the new PM. "I'll just hammer out a deal with the vendor for the needed data." Unfortunately, the sticker price will often be a show stopper. "How can Company XYZ believe its data is worth that much! Who can I talk to?" The answer, in short, is nobody. This scenario has played out in government program offices for longer than anyone would care to admit. A coherent strategy is needed to improve the situation.

It is not enough to blame the previous PMs—their decisions not to buy the data were often based on very reasonable arguments. It was expensive. It was not needed then, or expected to be needed any time soon. The contractor was not interested in releasing its proprietary rights or intellectual property. Budgeting and obtaining the funds then, would have delayed critical progress in the early phases. The projected need date for using the data was years out based on the current operating and support concepts. All of these seemed like real and valid reasons at the time.

Even when PMs buy the data early, it often becomes outdated over the years as the physical configurations for systems evolve. When the data eventually gets pulled off the shelf, a great deal more money is often required to get it up-to-speed with all the current configurations.

The early PMs were not evil, ignorant villains. Instead, they were professional planners, juggling complex combinations of possible program plans. Eliminating the purchase of expensive data removed what was then a low priority, high expense factor. Their decisions immediately improved their *big three* metrics—cost, schedule, and performance. All three areas probably looked better the instant the purchase of data was removed from the equation. The decisions thus made perfect sense from their perspective. But years later, with new PMs in charge, far removed from those early decisions, the reality can be quite different! Why? Short and simple, things change—new plans emerge; leadership transitions; priorities evolve; Congress redirects funds; some partnerships grow and others die, and specific threats come and go. Real life is a living breathing animal—that isn't a bad thing, it is just reality. This new reality is magnified even further in DoD's new evolutionary acquisition environment. Air Force acquisition programs from the outset will now be designed to change from increment to increment, implementing the time-

phased requirements of users taking advantage of maturing technology over time. Planned change is the new reality. The real question is not who is to blame, or how did this bind materialize, it is: "How can this dilemma be avoided?"

How Can the Dilemma Be Avoided?

The question policymakers must ask is what can the acquisition community do to reduce the likelihood that this dilemma will affect future systems? What can be changed about the acquisition process to reduce the chance of seeing unreasonably high costs and unacceptably large negative consequences associated with the delayed, late, or nonexistent purchase of tech data?

One fairly straightforward technique is available to do just that. This technique does not require hiring expensive consultants to reengineer the process, top to bottom, turning old ways on their ears, and requiring remedial education and training to make it happen. An excellent solution is for a PM to simply require the vendor to include a series of prepriced options to buy the various portions of all the data. The PM then uses the options as an important part of the evaluation process in competitively selecting the best vendors for the new program or program upgrade. A series of options means there are multiple contract options included that, when taken together, include all of the associated tech data. This generally includes operating and maintenance manuals, engineering drawings, interface control documents, and specifications. If a data item is needed in the future, not only will there already be a contract vehicle in place to buy it, but the price paid will already have been established in a competitive environment. There will be no last-minute surprises, the price will be as low as possible, and informed planning can take place. That is about the best scenario to ask for.

For example, quite often in the Air Force, it is decided a few years after the initial fielding of a system to change the support strategy. The support providers will need the data to successfully implement the change and economically maintain the system for the remaining portion of its life cycle. In all too many cases, the data was not bought, and now it is needed. The original source will likely be the only source for that information. The contractor knows it and so does the PM. The data rights are proprietary and at this point, even more valuable (read expensive). At this point, the new PM is over the proverbial barrel. Of course the contractor is going to value the data highly and price it accordingly. This is not evil or conspiratory. It is reality. It is the way of our capitalistic society.

So why does the solution include soliciting "...a series of options" rather than just one big option that includes all the data? Breaking the requirement down to its component parts gives the current and future PMs the flexibility to pick and choose only the data that is needed, when it is needed. All the data may not be needed simultaneously, so why pay for it all as one big package? If, for example, under a new support strategy, only the repair manuals are needed, why buy the design drawings too? Exercise the appropriate option and pay just the bill for the data that is needed. PMs must work closely with their procurement

team to decide what makes the most sense and what is doable under applicable guidance.

Finally, PMs should use the data options and pricing as a principal piece of the proposal evaluation process when selecting the best original vendor for the new system. Meaningful inclusion in the evaluation factors will help ensure contractor prices are set at the best possible level. The data evaluation should not be the number one concern, but if these data options are not meaningfully included at all in the evaluation factors, then the price will not be set competitively. The hands of future PMs will be tied tightly behind their backs and their alternatives will be severely limited. Then, as systems progress through their life cycles and plans change (for whatever reason), future PMs may end up paying dearly to get the necessary data, if they can get it at all.

Conclusion

A good solution to the PM's tech data dilemma is to first bite the bullet and buy the data that is absolutely necessary to support current operating and support plans. For data not bought immediately, PMs should also put in place a series of prepriced options for all of the data on the original solicitation, and use those options as a meaningful piece of the proposal evaluation process.

Does this strategy eliminate all problems? Will it ensure that data will be cheap and readily available in all situations? Of course not. Data rights will remain an expensive, complex, and vexing issue. The more time that elapses between the start of the program and the need for the data, the more complications can creep up, even with defined, prepriced options in place. Vendors can legitimately claim that the negotiated prices are only good for a limited period of time. Also, the data portion of one vendor's proposal probably would not be the sole reason to eliminate or select them in the original competition. The data portion, however, should be a meaningful factor that is considered as part of the overall, best value package.

The technique described in this article will help ensure PMs do not pay more than is absolutely needed. It doesn't guarantee the data will always be there or always be cheap. Further, it does not spell out exactly what to buy and when. Those decisions will always be determined on a case-by-case basis, dependent on risks, costs, trade-offs, and program peculiarities. The PM and his or her procurement team will have to analyze and work these issues out to determine what makes the most sense for the life-cycle operation and to support their individual program. The technique described herein is not the panacea, but it is a big step in the right direction.

Mike Farmer, Bob Flagg, and Guy Fritchman are course directors for several of the professional continuing education courses in acquisition and logistics at the Air Force Institute of Technology. All have a variety of credentials to include Program Management Professional certification and Acquisition Professional Development Program Level 3. Each holds multiple graduate and undergraduate degrees.



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Introduction

In a white paper published by the Auto-ID Center at the Massachusetts Institute of Technology (MIT), Vivek Agarwal said that, in order to achieve real-time visibility of information, the following are needed:¹

- Real-time data acquisition methods
- Conversion of acquired data into relevant information using standardized, secure representation
- Instantaneous access to this information

These points could not apply more to the United States Air Force.

All code-reading systems for automatic identification share the following generalized description. There is an item needing to be tracked and its accurate identification throughout the supply chain will be beneficial to the organization. Some form of coding device, such as a label or tag, is affixed to the item so that a wide range of information can be automatically read from the device. The code will be read from the device by any of a number of technologies including an automatic or hand-held bar code reader, optical character reader, magnetic stripe reader, vision system, or radio frequency interrogator. Once the code is read, it will be validated and converted into *system-meaningful* control and information output. The code reader transmits the output to other technologies (computers and so forth) for data manipulation or communication.²

Tags and Readers—Radio Frequency Identification

RFID Defined

Radio frequency identification (RFID) uses a radio frequency transmission to identify a person or object. A RFID transponder or tag responds to a radio signal sent by a reader. Tags store information such as a serial number, model number, color, or any other characteristics that may be of benefit. Tags are read by a compatible reader when they pass through its radio frequency field.

Article Acronyms

CIO – Chief Information Officer
DNS - Domain Name System
EPC - Electronic Product Code
JTAV - Joint Total Asset Visibility
MIT - Massachusetts Institute of Technology
NSN - National Stock Numbering
ONS - Object Naming Service
PML - Physical Markup Language
RFID - Radio Frequency Identification

RFID is not a recent discovery. It was first implemented in World War II as a means of identifying friendly aircraft. However, only recently has RFID gained attention as a valuable method of identifying objects on a large scale.

Active Versus Passive RFID

Active RFID and passive RFID technologies are often combined as a whole when referring to RFID; however, they are fundamentally distinct technologies with substantially different capabilities. Effective supply chains do not rely solely on one particular technology, but use both active and passive technologies in complementary ways for complete visibility.³

Both active and passive technologies utilize radio frequency energy to communicate between a tag and a reader; however, the technologies differ by the means in which they are powered. Active RFID utilizes an internal power source (battery) for a continuous source of power. Passive RFID utilizes radio frequency energy from the reader to obtain its power. Because passive RFID relies on a reader, a passive tag is only on when it is communicating with a reader.

Applications of Active and Passive RFID to Supply Chain Visibility

Passive RFID is best suited for applications where the movement of materiel is conducted in a highly consistent and controlled environment, and where there is not a need for security or sophisticated data storage or manipulation. Active RFID is more appropriate where materiel flow is dynamic and unconstrained, and where there is a need for enhanced security and data capabilities. Savi Technology outlines some of the main tasks of supply chain visibilities and recommends which RFID technology is best for each.⁴ These tasks are outlined in the discussion that follows

Area Monitoring

Active RFID is the only practical technology for area monitoring. Because of the continuous nature of monitoring, only active RFID has the power supply for such applications. Savi Technology suggests active RFID for the following types of area monitoring:⁵

- Collecting real-time inventory information within a warehouse
- Monitoring the location of empty and loaded air cargo containers across an air terminal or tarmac
- Monitoring the security of ocean containers or trailers stored in a yard or terminal

Spot-Level Locating

One means by which RFID enables visibility is by automatically collecting data on materiel as it flows through the processes. In order to accomplish this, readers must be precisely located at specific points within a process. Savi Technology provides the following examples of spot level location:⁶

- Identifying the exact parking slot of vehicles in a truck yard
- Identifying the specific storage rack of a pallet within a distribution center
- Identifying the specific loading bay in current use by an air cargo unit load device

High-Speed, Multi-Tag Portal Capability

A variety of portals can exist in a supply chain. By definition, a portal is any type of doorway, gate, or opening through which materiel flows. Examples may include dock doors at a distribution center, entry or exit gates at an intermodal terminal, and conveyor checkpoints in a parcel sorting operation.

In order for a reader to identify multiple tags flowing through a portal, it must be able to collect information from multiple tags at high speed, while at the same time differentiating between the tags within the specified portal area and those in surrounding areas. Large-scale application, such as roadside monitoring, is available only with active RFID because it has the necessary range. Passive RFID can handle small to medium size portals such as doorways and conveyor checkpoints, but lacks range and can only read tags moving relatively slowly (5 to 10 mph or less). Dual-range active RFID offers the most versatile means of identifying multiple tags through a portal. It is capable of reading tags at a very high speed (greater than 60 mph) and can handle small, medium, and large scale applications.

Cargo Security

RFID can offer cargo security through electronic seals. Both active and passive RFID have their place in security, depending on the application and level of security needed. Passive RFID is only able to detect whether a seal has been broken. The lack of a power source prevents passive RFID tags from being able to continuously monitor the seals and record status throughout the journey. Active RFID is, however, able to continuously monitor cargo and record the date and time of a potential breach and also employ sophisticated *anti-spoofing* techniques to prevent thieves from damaging the integrity of the tag.

Electronic Manifest

Electronic manifests will play an important role in deployment situations. A major concern during Operation Desert Storm was the lack of visibility into Air Force containers. For cargo containers carrying a variety of materiel, it may be necessary to store an electronic manifest within a tag itself so every element of materiel can be automatically updated and checked into a database. Active RFID is the preferred method to store such large amounts of data, and is capable of offering electronic manifest capabilities built into the tag. Passive RFID can only be used to transmit an electronic product code (EPC) number that points to a manifest on an external database.

In addition to the above listed advantages of active RFID, a major advantage is the minimal impact it places on the overall supply chain process compared to passive RFID. Passive RFID will restrict and restrain materiel flow because it has a very short communication range. This could mean materiel movement systems (conveyors) require modification to accommodate the communication range restrictions. In addition, passive RFID has difficulty with multiple tag collection and requires that materiel be adequately spaced so that interference is minimized. Passive RFID may also slow down the materiel movement process since

it can only read tags at relatively low speeds. The low cost of passive tags must be compared with the potential time savings of active RFID in the supply chain.

Both active and passive technologies have their place within the Air Force supply chain. Active RFID should be implemented for the most part, but there are specific areas where passive RFID may be used to reduce cost.

Implementation

RFID, combined with an effective database system, will give the Air Force complete visibility into its supply chain. The Air Force will have the ability to locate materiel anywhere in the world in real time.

The Air Force should begin its tagging program at the pallet or container level and work down from there to case tagging, and eventually item tagging. Item tagging will offer the most benefit to the Air Force, but it is the most difficult to implement. Implementing tagging in phases will allow the Air Force to gradually adjust to automatic identification and RFID technology. This will greatly reduce the number of readers that initially need to be installed in the Air Force supply chain infrastructure.

In order for RFID to be fully implemented, all materiel must be tagged. This is best accomplished by the manufacturer in the production stage so that the tag is internal and protected from damage and tampering. The Air Force will need to embark upon a program that gets manufacturers of Air Force products to tag their parts and products during the manufacturing stage. This will be a difficult task since tagging parts will require retooling, and in some cases, require redesigning the part itself. All parts of assemblies and aggregates that need to be explicitly tracked must be tagged.

Readers will have to be distributed throughout the Air Force supply chain and anywhere tags will need to be read. Readers will need to be installed at all warehouse and depot areas. For the monitoring of aircraft, readers should also be placed on the flight line for spot-level locating of specific aircraft.

Codes and Languages

Within the memory chip of the smart tags, an EPC (128-bit code) is embedded for each individual product. As smart tags are scanned by readers, their EPC is transmitted to the Internet where a database stores all of the information for that particular code.

The EPC works together with the Physical Markup Language (PML) and the Object Naming Service (ONS). PML is a standard language for describing physical objects to the Internet analogous to the Hypertext Markup Language, which is the standard language used to display web pages. The ONS is very much like the Internet's current Domain Name System (DNS). The ONS is a computer system that acts as a database, storing all information about any particular EPC, just as the DNS stores the Internet Protocol addresses for all text-based web-site names. The ONS database will probably be significantly larger than the DNS server as it will have to store an EPC number for each object that carries an EPC.⁷

Physical Markup Language (PML)

PML is intended to be a common language for describing physical objects, processes, and environments. It provides a general, standard way of describing the physical world. The

purpose of PML is to provide a language for remote monitoring and control.

PML seeks to provide broad definitions of objects, describing them in terms of characteristics that are common to all physical items. This allows the language to be implemented across multiple industries and applications, rather than one particular focus. PML tries to provide a single representation for a physical object. If there are multiple ways to describe the same object, PML will arbitrarily select one so that data translation occurs when encoding or viewing, not in interpreting what is being viewed.⁸

Electronic Product Code

The EPC was developed as a way to identify all physical objects. The EPC is designed with capacity to enumerate all items that exist in the world, and handle all current and future naming methods. The EPC will be the basis by which to gain database information on a particular item. The EPC will act as a serial number so that the product may be looked up and all of the information known may be accessed. The EPC differs from the current standard, the uniform product code, in that it is able to identify each individual item, not just classes or types of items. The task of enumerating all these is daunting, and requires a code that has a tremendous amount of capacity.

Implementation

It is recommended that the Air Force adopt the Auto-ID Center's EPC for identifying individual items. This 128-bit code has the capacity to handle each individual item of Air Force materiel and not just classes or types of items. The EPC would allow the Air Force to track a particular part for a particular plane throughout its life and log its use and repair history. The EPC would not replace the current National Stock Numbering (NSN) System implemented by the Air Force. The NSN would still be needed to identify classes and types of products. An EPC should be automatically generated by the database for every individual item the Air Force wishes to track or monitor. It is also recommended that the Air Force adopt the PML developed by the Auto-ID Center. PML is the link between the EPC and the ONS.

Databases

The Air Force should phase out all of its subsidiary databases that serve various niches of the Air Force and replace them with a single, all-purpose database that every user can access from anywhere in the world. Meeting this second requirement suggests that the database should be Internet-based and have the capability of tracking all types of assets.

The Joint Total Asset Visibility (JTAV) 2020 initiative suggests a common database that is fed data at predetermined intervals from one of the many subsidiary databases that currently exist. It would prove much more efficient if the primary database were developed with the capability to perform all Air Force supply chain tasks so that personnel at the beginning of the chain can use it to enter data and retrieve information. Under the current JTAV initiative, the burden would still be on the user of the supply chain to choose which system to update based on the particular piece of material. Furthermore, none of the existing databases currently have the capability of tracking individual parts, only classes or types of items. The Air Force should have

a single database that may be accessed by any user via the Internet. This would eliminate the need to have specialized terminals with dedicated communication lines such as those required by the Standard Base Supply System or special software as required by the Mission Capable Asset Sourcing System. The user would only need a PC with an Internet connection that would connect directly with the master database located on remote servers.

This database would necessitate an extraordinary amount of data storage. Capacity would be measured in terabytes not gigabytes. This database would have to accommodate the specifications and history log of every individual item the Air Force possesses.

The database should be located on a secure server with substantial firewall protection. Access to the database should be allowed only with a user ID and a password. Different levels of security should be allotted to Air Force personnel based on what information each particular person needs to access.

Deciding on Standards

Standards for RFID have been slow to develop over the years. The International Standards Organization, the Uniform Code Council and the Auto-ID centers at MIT and Cambridge University are among the parties developing standards.

There are several initial steps the Air Force and military in general must undertake in order to embark upon the challenge of total-asset visibility. The first is choosing standards. Standards must be chosen on several levels—from what RFID frequencies to use, to what serial number methodology to use in identifying products, to what type of database and computer platform to use for a consolidated database. The Air Force is a large enough entity that it could form its own standard or the DoD could form its own standard separate from commercial industry. The Air Force, and the DoD in general, uses a lot of proprietary products and has its own infrastructure. With this in mind, separate Air Force standards would not create a large problem because its supply chain is a closed system with regard to military-specific items.

Wal-Mart as a Model

Wal-Mart is always on the forefront of emerging technology and, because of its dominating position in the market, has the ability to enforce any implementations it wishes to impose. In June of 2003, Wal-Mart set the date of January 2005 for RFID implementation.⁹ This meant that by that date, the top 100 suppliers had to work with Wal-Mart by using RFID to track pallets of goods throughout its supply chain. Linda Dillman, Wal-Mart's CIO, noted that "At some point, like any other technology, like EDI, it'll be a requirement for doing business with Wal-Mart."¹⁰ The Air Force, as with Wal-Mart, has the force in the market place to make these kinds of demands on its suppliers.

Conclusions

In this article we reviewed much of the current technology for improving supply chain visibility and made recommendations as to how this technology might be implemented within the Air Force in order to support its JTAV 2020 initiative. Implementing such an overhaul of the supply chain and incorporating cutting-

edge technology cannot be done overnight but will probably take decades to complete. Gradual, step-by-step, implementation will be necessary to ensure a smooth transition.

Notes

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AF/A9 Logistics Analysis: Setting the Gold Standard

Major Andrew Hunt, USAF

Quick quiz. Do you know what organization provides top-notch operational analyses to the Air Force's senior leaders? Those of you that said the Air Force Studies and Analyses Agency (AFSAA) *would* have been right. Prior to 1 February 2006, AFSAA set the gold standard for Department of Defense analysis. And after 1 February? Well, only the name has changed. As part of the Headquarters realignment to the A-Staff construct, AFSAA (a former direct reporting unit) has merged with the Office of Lessons Learned to form HQ USAF/A9, the Studies & Analyses, Assessments and Lessons Learned Directorate. A9 is still charged with delivering fireproof analyses to the Air Force's *Top IV* (including the Secretary of the Air Force, the Chief of Staff, Air Force, and the Vice Chief of Staff, Air Force). We think we do a pretty good job, and others agree.

So, what does this have to do with logistics? A9 has a select group of forward-thinking loggies that sit in a very unique position. We are charged with ensuring that key logistics feasibility and supportability issues are addressed when conducting operationally focused studies and analyses. For example, if a study is looking at an increase in tankers for a particular warfighting scenario, it is our charge to provide the analysts with tanker basing options that not only address operational considerations, but also incorporate a base's existing and projected logistics support capabilities. These

considerations, in the opinion of many, have been missing from such studies for some time. The bottom line is that A9's logistics analysts are doing our part to ensure that the issue of logistics is not *magic wandered* away.

The future of the logistics efforts at A9 is growing brighter everyday. Our team now consists of a mix of supply, fuels, logistics plans, and maintenance expertise. We are continuously seeking to establish or expand partnering relationships with the Headquarters Air Force A4/7 directorate, major command logistics analyses operations, and the Air Force Logistics Management Agency. We constantly keep our ears to the ground so that we can stay on top of current issues in Air Force logistics. Our goal is to continue to find ways to bring the weight of logistics to the analyses that will shape our Air Force in the future.

For more information, please contact one of the following logisticians on the A9 staff:

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DSN 425-8653

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The Dimensions of Logistics

Lieutenant Colonel James C. Rainey, USAF, Retired
Cindy Young
Roger D. Golden, DPA

Defining Logistics

The word logistics entered the American lexicon a little more than a century ago. Since that time, professional soldiers, military historians, and military theorists have had a great deal of difficulty agreeing on its precise definition.¹ Even today, the meaning of logistics can be somewhat *fuzzy* in spite of its frequent usage in official publications and lengthy definition in Service and Joint regulations. Historian Stanley Falk describes logistics on two levels. First, at the intermediate level:

Logistics is essentially moving, supplying, and maintaining military forces. It is basic to the ability of armies, fleets, and air forces to operate—indeed to exist. It involves men and materiel, transportation, quarters, depots, communications, evacuation and hospitalization, personnel replacement, service, and administration.

Second, at a higher level, logistics is:

...economics of warfare, including industrial mobilization; research and development; funding procurement; recruitment and training; testing; and in effect, practically everything related to military activities besides strategy and tactics.²

While there are certainly other definitions of logistics, Falk's encompassing definition and approach provide an ideal backdrop from which to examine and discuss logistics. Today, the term combat support is often used interchangeably with logistics.

The Themes of US Military Logistics

From a historical perspective, ten major themes stand out in modern US military logistics.³

- The tendency to neglect logistics in peacetime and expand hastily to respond to military situations or conflict.
- The increasing importance of logistics in terms of strategy and tactics. Since the turn of the century, logistical considerations increasingly have dominated both the formulation and execution of strategy and tactics.
- The growth in both complexity and scale of logistics in the 20th century. Rapid advances in technology and the speed and lethality associated with modern warfare have increased both the complexity and scale of logistics support.
- The need for cooperative logistics to support allied or coalition warfare. Virtually every war involving US forces since World War I has involved providing for, and, in some cases, receiving logistics support from allies or coalition partners. In peacetime, there has been an increasing reliance on host-nation support and burden sharing.
- Increasing specialization in logistics. The demands of modern warfare have increased the level of specialization among

support forces.

- The growing tooth-to-tail ratio and logistics footprint issues associated with modern warfare. Modern, complex, mechanized, and technologically sophisticated military forces, capable of operating in every conceivable worldwide environment, require that a significant portion, if not the majority of the budget, be dedicated to providing logistics support to a relatively small operational component. At odds with this is the need to reduce the logistics footprint in order to achieve the rapid projection of military power.
- The increasing number of civilians needed to provide adequate logistics support to military forces. Two subthemes dominate this area: first, unlike the first half of the 20th century, less reliance on the use of uniformed military logistics personnel and, second, the increasing importance of civilians in senior management positions.
- The centralization of logistics planning functions and a parallel effort to increase efficiency by organizing along functional rather than commodity lines.
- The application of civilian business processes and just-in-time delivery principles, coupled with the elimination of large stocks of spares.
- Competitive sourcing and privatization initiatives that replace traditional military logistics support with support from the private business sector.

Logistics and Warfare

General Matthew B. Ridgway, of World War II fame, once observed, "What throws you in combat is rarely the fact that your tactical scheme was wrong ... but that you failed to think through the hard cold facts of logistics." Logistics is the key element in warfare, more so in the 21st century than ever before. Success on the modern battlefield is dictated by how well the commander manages available logistical support. Victories by the United States in major wars (and several minor wars or conflicts) in the 20th century are linked more directly to the ability to mobilize and bring to bear economic and industrial power than any level of strategic or tactical design. The Gulf War and operations to liberate Iraq further illustrate this point. Long before the Allied offensive could start, professional logisticians had to gather and transport men and materiel and provide for the sustained flow of supplies and equipment that throughout history has made possible the conduct of war. Commanders and their staffs inventoried their stocks, assessed the kind and quantities of equipment and supplies required for operations in the severe desert climate, and coordinated their movement plans with national and international logistics networks. *"The first victory in the Persian Gulf War was getting the forces there and making*

certain they had what they required to fight [Emphasis added]. Then and only then, would commanders initiate offensive operations.”⁴ The same may be said of lightning quick victory in Iraq, although without the massive stockpile of inventory seen during the Gulf War.

In 1904, Secretary of War Elihu Root warned, “Our trouble will never be in raising soldiers. Our trouble will always be the limit of possibility in transporting, clothing, arming, feeding, and caring for our soldiers...”⁵ Unfortunately, the historical tendency of both the political and military leadership to neglect logistics activities in peacetime and expand and improve them hastily once conflict has broken out may not be so possible in the future as it has been in the past. A declining industrial base, flat or declining defense budgets, force drawdowns, and base closures have all contributed to eliminating or restricting the infrastructure that made rapid expansion possible. Regardless, modern warfare demands huge quantities of fuel, ammunition, food, clothing, and equipment. All these commodities must be produced, purchased, transported, and distributed to military forces. And of course, the means to do this must be sustained.

The End of Brute Force Logistics

The end of the Cold War and experience gained from the conflicts in Grenada, Panama, and the Persian Gulf essentially brought the era of *brute force* logistics to a close. The traditional practice of using massive quantities of troops and large stockpiles of supplies available in theater to engage sizable hostile forces is obsolete. Additionally, extensive buildup time and lengthy resupply and repair pipelines to sustain forces are unrealistic. The focus of logistics has now shifted toward rapid movement of small, independent force packages to employ precise combat power anywhere in the world. The rapid changes in political dynamics of the world powers, domestic fiscal constraints, and technological advances have rendered the Cold War military strategy and preparation ill-equipped to handle 21st century missions, requirements, and demands.

Logistics Challenges

The US role in the post-Cold War world has changed dramatically. Although currently heavily involved in the Global War on Terrorism, military forces are no longer dedicated solely

to deterring aggression but must respond to and support homeland defense and humanitarian missions. From peacekeeping to feeding starving nations, to conducting counterdrug operations, the military continues to adapt to evolving missions. Logistics infrastructure and processes must evolve continuously to support the new spectrum of demands. The keys to supporting both combat and peacetime operations successfully are robust, responsive, and flexible logistics systems.

Decreases in funding and the drawdown of the US military in the 1990s drove new approaches to logistics support and refinement of the military logistics systems. These fiscal constraints dictated that the military reduce infrastructure, maintain a smaller amount of inventory and fewer personnel, and find ways to reduce costs without degrading mission capability.

Reduced budgets impact weapons modernization programs in several ways. As dollars decrease, fewer systems can be developed, which increases the importance of decisions made in the acquisition process. The process must develop the most lethal systems while emphasizing reliability and supportability. Therefore, logistics considerations play a more important role than ever in the design, production, and fielding of new systems. Logistics capabilities for supporting future forces require systems to be *smarter* and require less maintenance.

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Mr Rainey is currently the Editor-in-Chief of the Air Force Journal of Logistics. He is a retired Air Force officer with more than 20 years of logistics experience. Ms Young is presently the editor of the Air Force Journal of Logistics. She has an extensive background in editing Air Force logistics manuals, particularly those used in the supply community. Dr Golden directs the Analysis Division at the Air Force Logistics Management Agency. He has published a variety of works and is an adjunct professor at Auburn University, Montgomery.

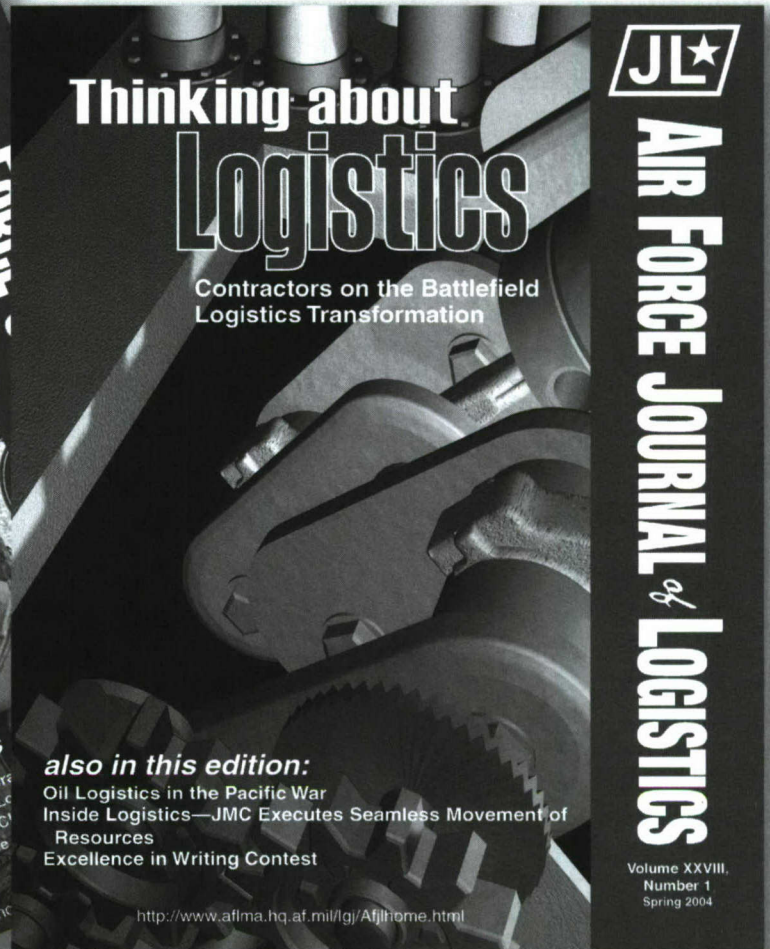
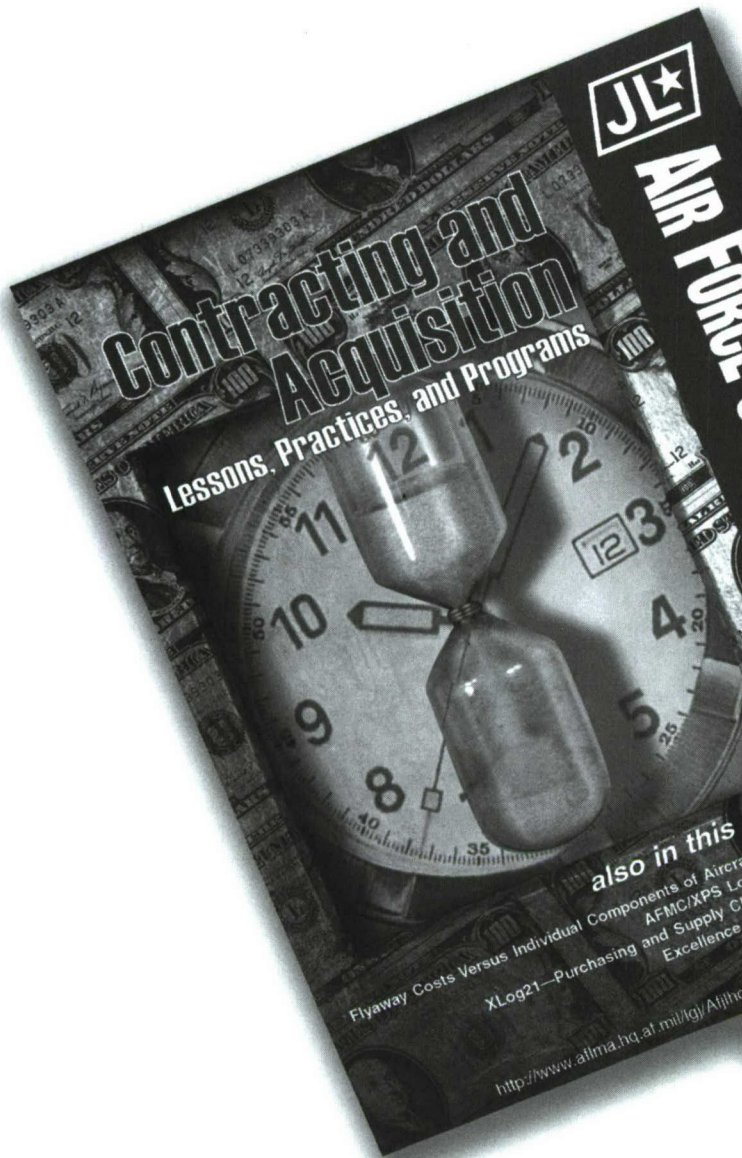


notable quotes

Focused Logistics comes from the idea that in the past spare parts were relatively inexpensive, but transportation to move them was expensive or in short supply. The way we overcame this problem was simple. Before beginning any major military operation, we would move forward a massive stockpile of spare parts, equipment, and munitions. If we consumed all those materials in the stockpiles, that was all well and good. If we did not, we would end up giving them away or pushing them into the ocean because it was more expensive to move them back to the United States than it was to destroy them in the field.

—Gen Ronald R. Fogleman, USAF

more than 2



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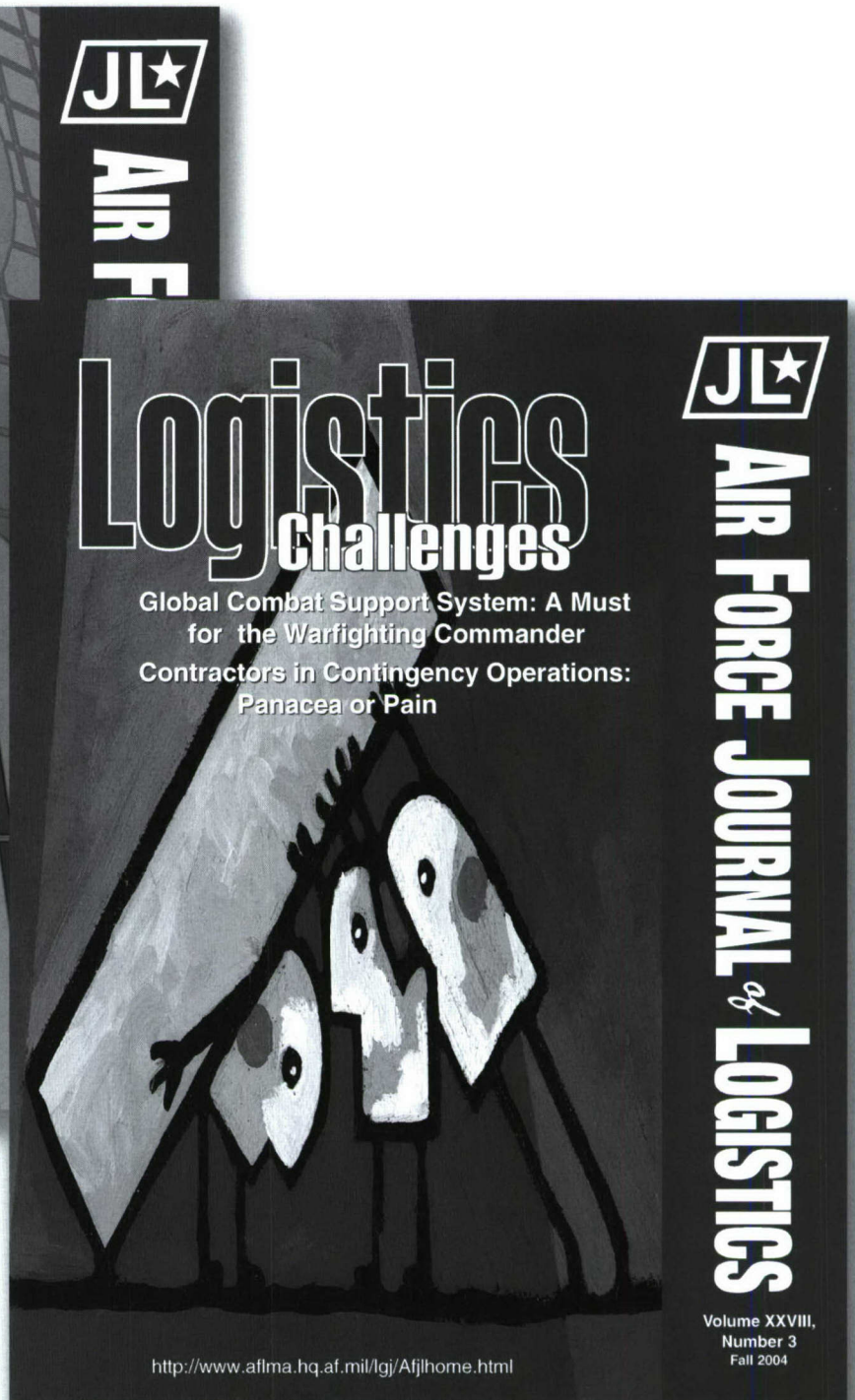
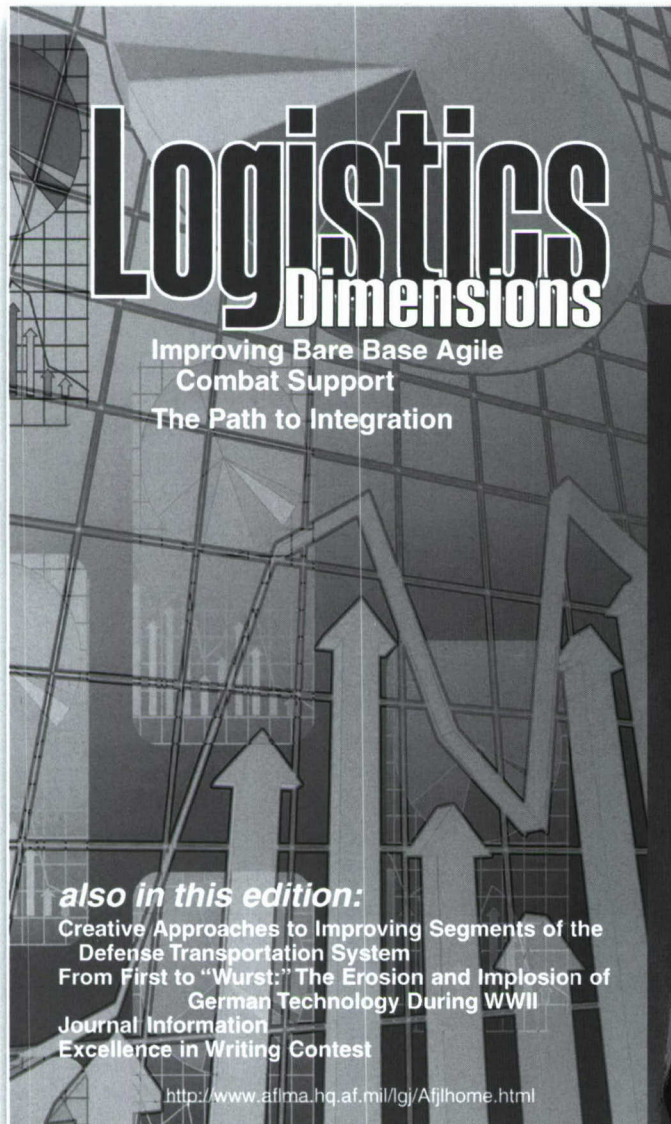
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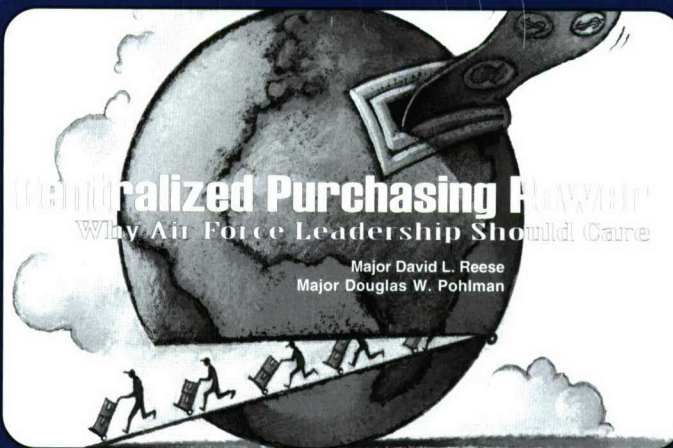
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Centralized Purchasing Power Why Air Force Leadership Should Care

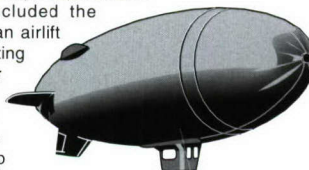
Major David L. Reese
Major Douglas W. Pohlman

The Editorial Advisory Board selected "Centralized Purchasing Power: Why Air Force Leadership Should Care"—written by Major David L. Reese, USAF and Major Douglas W. Pohlman, USAF, Vol XXIX, No 1—as the most significant article to appear in the *Air Force Journal of Logistics* in 2005.

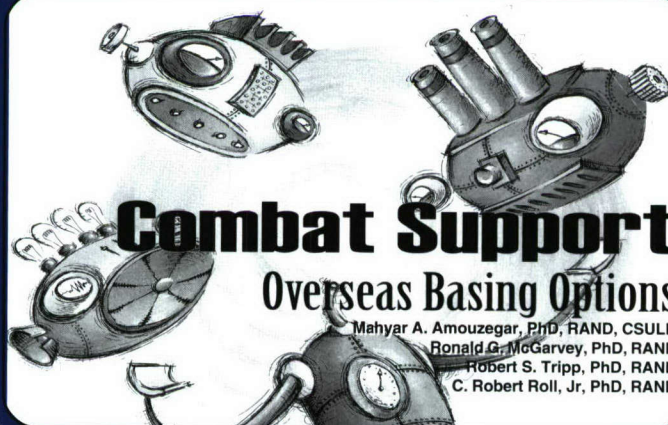
Lessons from History | Colonel Walter O. Gordon, USAFR
Colonel Chuck Holland, USAF, Retired

airships and the revolution in strategic airlift Back to the Future

The last major study of US airlift requirements, *Mobility Requirements Study 2005* concluded the United States requires an airlift fleet capable of transporting 54.5 million ton-miles per day (MTM/D). Recent developments indicate the requirement will be even higher, perhaps up to 60 MTM/D.



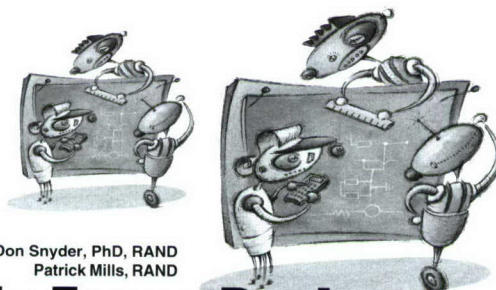
"Back to the Future: Airships and the Revolution in Strategic Airlift"—written by Colonel Walter O. Gordon, USAFR and Colonel Chuck Holland USAF—was chosen as the most significant historical article to appear in the *Air Force Journal of Logistics* in 2005.



Combat Support Overseas Basing Options

Mahyar A. Amouzegar, PhD, RAND, CSULB
Ronald G. McGarvey, PhD, RAND
Robert S. Tripp, PhD, RAND
C. Robert Roll, Jr, PhD, RAND

The Editorial Advisory Board selected "Combat Support: Overseas Basing Options"—written by Mahyar A. Amouzegar, PhD, RAND, CSULB; Ronald G. McGarvey, PhD, RAND; Robert S. Tripp, PhD, RAND; and C. Robert Roll, Jr, PhD, RAND—as the most significant article to appear in Vol XXX, No 1 of the *Air Force Journal of Logistics*.



Don Snyder, PhD, RAND
Patrick Mills, RAND

Air Force Deployments Estimating the Requirement

The Editorial Advisory Board selected "Air Force Deployments: Estimating the Requirement"—written by Don Snyder, PhD, RAND and Patrick Mills, RAND—as the most significant article to appear in Vol XXX, No 2 of the *Air Force Journal of Logistics*.